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Technical Report 1011

Training Dismounted Soldiers in Virtual Environments: Task and Research Requirements

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EDGAR M. JOHNSON
Director

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For this report, research was conducted to investigate the suitability of virtual environments (VE) for individual combatant training. The behaviors required by selected Dismounted Infantry and Special Operations Forces missions were linked to estimates of the availability of VE technology to support their performance. A baseline research plan was then developed as a series of vignettes in which research participants would perform the activities in clusters with similar technology demands and performance characteristics. Subsequent experiments and demonstrations were proposed to combine the activities into complete Army Training and Evaluation Program tasks. Functional requirements for a VE testbed were identified, and possible hardware and software elements were defined.

No missions or tasks can be fully supported by VE at this time, but most can be partially supported. This report provides a link between dismounted soldier tasks and estimates of the VE characteristics required to support their simulated execution and training. This information will be useful in making decisions about acquisition of or investment in the development of VE technology to support dismounted combatant training.

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Human Performance Effectiveness and Simulation

FOREWORD

The Army has made a substantial commitment to Distributed Interactive Simulation (DIS) and the electronic battlefield for training, concept development, and test and evaluation. The current DIS training system, Simulation Networking (SIMNET), and the next generation system, the Close Combat Tactical Trainer (CCTT), provide effective training for soldiers fighting from vehicles, but not for individual dismounted soldiers. Virtual Environment (VE) technology has the potential to provide Individual Combat Simulations (ICS) for the electronic battlefield.

This report describes work conducted to analyze the requirements for using VE for Individual Combat Simulations and links them with the results of prior human performance and training research to identify research needs. Those needs form the basis for developing a research plan and research facility.

Following a series of interim briefings, the results of this research were briefed to the Army Simulation, Training, and Instrumentation Command on 3 July 1993.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Simulator Systems Research Unit conducts research to improve the effectiveness of training simulators and simulations. The work described is a part of the ARI research task titled "VIRTUE—Virtual Environments for Combat Training and Mission Rehearsal."

EDGAR M. JOHNSON
Director

TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: TASK AND RESEARCH REQUIREMENTS

EXECUTIVE SUMMARY

Requirement:

The Army has made a commitment to Distributed Interactive Simulation (DIS) as the primary resource for conducting collective training and for planning and rehearsing military operations. The current DIS training system, Simulation Networking (SIMNET), and the next generation system, the Close Combat Tactical Trainer (CCTT), provide effective training for soldiers fighting from vehicles, but are unable to do the same for individual dismounted soldiers. The recent intense developmental interest and rapid progress in the area of virtual environment (VE) technologies provides the potential to involve dismounted combatants in these environments. Recognizing the potential of this technology to support individual combatant training, mission planning, and mission rehearsal, this research was conducted to investigate the suitability of virtual environments for these purposes.

Procedure:

Missions and tasks from Dismounted Infantry and Special Operations Forces Army Training and Evaluation Programs (ARTEPs) were screened to reflect applicability to echelon, mode of movement, classification, and general appropriateness for training in VE. The behaviors required by the selected missions and tasks were linked to estimates of the availability of virtual environment technology to support the performance of those behaviors. Tasks and activities (task components) were prioritized to create a sequence of research and demonstrations of task performance in a virtual environment. A research plan was developed as a series of vignettes in which research participants would perform the prioritized activities in clusters with similar technology demands and with similar performance characteristics. Subsequent experiments and demonstrations are proposed to combine the activities into complete ARTEP tasks. Functional requirements for a virtual environment testbed were identified, and possible hardware and software elements were defined.

Findings:

Missions and tasks taken from four ARTEPs that addressed squad or team performance were assigned numerical values, indicating the availability estimates for virtual environments to support them. An assessment of these pairings indicates that no missions or tasks can be fully supported by virtual environments at this time. The great majority of missions and tasks, however, can be partially supported by VE technology.

The prioritization of activities and tasks indicated that research could be conducted in three distinct phases corresponding with the availability of virtual environment technology to support the performance of the activities. The research plan capitalizes on this logical grouping of activities and tasks with a recommended series of vignettes to be demonstrated.

Utilization of Findings:

This report provides an essential link between dismounted soldier tasks and estimates of the virtual environment characteristics required to support their simulated execution and training. This information will be useful in making decisions about acquisition of or investment in the development of virtual environment technology to support dismounted combatant training. The research plan is a baseline that will be revised to meet changing task and resource requirements.

TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: TASK AND RESEARCH REQUIREMENTS

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TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: TASK AND RESEARCH REQUIREMENTS

INTRODUCTION

Purpose

Simulation technology developed over the past decade has produced an ability to synthesize a tactically realistic virtual battlefield that can be accessed by a large number of combatants at geographically dispersed remote locations. The early emphasis in this development has been on creation of an arena and model representations of combat resources required to conduct joint combined arms exercises. This was necessary so that the feasibility of such distributed simulation as a training environment for collective combat skills could be assessed. Researchers have focused on the representation of armor, aviation, artillery, command and control, and close air support functions for two reasons: (a) they bring a broad range of combat systems and activities to the virtual battlefield for test; and (b) they were able to be represented within the state of available technology. Tests of the feasibility of the technology have resulted in its embrace by the operational and training communities of the armed forces. The Government's commitment to distributed simulation as the primary resource for conduct of collective training and for planning and rehearsal of military operations is evident in the ongoing procurement of and operational exploitation of the technology.

The conduct of individual combat, through the introduction to the virtual battlefield of representations of individual soldiers, had to be deferred because the number and complexity of models required to represent even a modest force of individual combatants exceeded the capacity of affordable real-time computing resources. The recent intense developmental interest, and resulting rapid progress, in the science of virtual environment systems brings new technology to bear on the challenge of individual combat simulation. These systems immerse individual participants into synthesized surroundings through their own direct sensory experience. The resulting perception is one of personal presence and direct exercise of behaviors in the virtual world rather than the alternative of controlling mediating tools or equipment (such as weapons or vehicles) that, in turn, produce observable effects in the virtual space. While existing requirements for individual immersion onto the virtual battlefield have not been met in the past because of limited technical capabilities, it is appropriate to focus renewed attention on these requirements since the emerging technology now offers the promise of practical solutions.

Recognizing that this new technology provides a possible basis for expanding the capabilities of distributed interactive simulation systems to support mission proficiency training, mission planning, and mission rehearsal for the individual Social

Sciences, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has sponsored this research investigation of the suitability of virtual environments for these purposes. This report presents the results of that effort, and includes a research plan and the functional design of a research testbed to support it.

Background

The most significant development in Army field training in the past two decades, Tactical Engagement Simulation (TES), ultimately spawned a whole industry based on lasers for simulating direct fire. Fortunately for the Army, its requirements for that technology were derived from behavioral research initiated by ARI. EFFTRAIN (World & Root, 1977), SCOPES (Shriver, Mathers, Griffin, Jones, Word, Root, & Hayes, 1975), REALTRAIN (Shriver, Mathers, Grivin, Jones, Wood, Root, & Hayes, 1975), and MILES (Hart & Sulzen, 1988) constituted just such a sequence as this report advocates: behavioral investigation as a forerunner for technical innovation.

The importance of this initiative by ARI for the Army can not be overstated. The Army has committed itself to broad applications of virtual environments not only for training, but also for operational rehearsal, for materiel acquisition (including operational testing), and for program analysis and evaluation. Indeed, the Army's Close Combat Tactical Trainer (CCTT), currently under development, promises to be the Army's largest investment in virtual environment technology since the completion of the precursor SIMNET program (Alluisi, 1991). Yet to date little attention has been paid to individual combatants on the combined arms virtual battlefields. Individual Combat Simulations (ICS) have not yet been developed, in an era when national strategy, Army force structure, and Army stationing assign prime roles to airborne, airmobile, and light infantry divisions, and to Special Operations Forces (SOF), whose combatants fight chiefly afoot.

The Requirement for ICS

What distinguishes contemporary military training from that of earlier eras is chiefly realistic simulation of combat at the cutting edge, that is, accurate representation of the tempo and outcome of tactical engagements at the level of the weapon system. The technologies enabling such tactical engagement simulation include: powerful, compact processors and facile intercomputer communications; devices for recording in detail and graphing vividly the performance of vehicles and weapons in mock battle; accurate digital models of terrain, weapons, and weapon effects, derived from evaluations of actual materiel; and modulated lasers and chip-controlled laser-detectors for replication of direct-fire ordnance. Various combinations of these have figured in training that has demonstrably raised the

lethality and improved the survivability of units in all of the U.S. armed services.

Forms of Tactical Engagement Simulation

Three forms of tactical engagement simulation (TES) have come into wide use within the past ten years (Gorman, 1991a):

Constructive TES. Mathematical constructs or models simulate combatants in each opposing force, their weapons, and their vehicles, and only battle staffs are subsistent. Examples: Army FAMSIM and Battle Command Training Program; Air Force BLUE FLAG and Warrior Preparation Center; Navy ENWGS; Marine Corps MTWS.

Constructive TES is a computer-assisted version of the wargames that have figured in military training for centuries. The digital computer is able to generate much more faithfully for a commander and his battle staff an environment reflecting the time urgencies, extensive information flow, and decisional pressures of modern battle than could old-style manual games.

Subsistent TES. Real weapons and vehicles are manned and employed by opposing forces, and simulation is confined to those interactions caused by weaponry. Examples: the Army's Combat Training Centers, Navy's TOP GUN, STRIKE UNIVERSITY and BFIT, Air Force's RED FLAG/DESERT FLAG, Marine Corps MTWAES.

Subsistent TES has been a logical outgrowth of the instrumentation for test and military experimentation made possible by digital computers and computerized communications, coupled, in the Army's case, with MILES.

Virtual TES. A synthetic battle environment is composed of networked simulators of weapon systems manned by combatants. Distances among these simulators can be extensive: intercontinental distribution is feasible using satellite communications. Examples: DARPA's SIMNET and ODIN, Army's CCTT.

Because virtual TES obviates the costs associated with the transportation of units to a site where subsistent TES is practicable, and the operating costs and wear and tear on vehicles, it is clearly attractive to services confronting reduced budgets. Virtual TES presently employs parallel computing and packet communications, and incorporates constructive TES. Combatants in simulators representing a friendly or Blue force can give battle to a semi-automated opposing or Red force. (That is, the Red force is responsive to direction by a few real "enemy" commanders,

but is also governed by models or constructs of the battle behavior of Red units using artificial intelligence or expert system programming.) Virtual TES, being almost wholly computerized, has the potential for capturing extensive and precise behavioral data on man-machine interfaces during TES.

The ICS Lacuna

All three forms of TES are seriously limited in their ability to exercise dismounted combatants. Constructive TES aggregates these so that individual performances are indiscernible. Subsistent TES instruments direct-fire weapons in the hands of dismounted combatants (rifles, machine guns, anti-tank and anti-aircraft weapons) but does not collect data on the humans who position these weapons. This omission extends to groups of individual combatants. (We still do not know today to what extent, under given conditions, individual riflemen will join a firefight, except through such potentially self-serving mechanisms as post-battle, and even post-war surveys.) Moreover, there is a class of dismounted combatants whose function is only indirectly associated with weapon system employment, and who are hence uninstrumented, and therefore invisible, to contemporary subsistent TES. Examples are scouts, observation posts, forward observers, laser designators, and combat engineers afoot. Virtual TES, currently configured around vehicular simulators, also largely ignores dismounted combatants. The inability to encompass individual performances constitutes an element of unreality in all forms of TES. On the one hand, the vulnerability of individual combatants may not be accurately portrayed, and their contribution to their unit's success thereby overblown. On the other hand, being uninstrumented, their true contributions may be unrecorded, and undervalued in the final estimate of what determined battle outcome.

ICS in Support of DoD Models & Simulations

The importance of TES-generated behavioral data was highlighted during the recent study of models and simulations conducted under the joint auspices of the Assistant Secretary of Defense, Force Management and Personnel, and the Director of Defense Research and Engineering. That study concluded that progress with models and simulations required

> empirically derived representation of the behavior of actual physical and human systems. Observations of that behavior should be sought in actual operations, in operational tests, or in training exercises that most closely replicate the complexities and friction of battle, such as large scale Tactical Engagement Simulation (TES). Use the most effective mathematics to model such behaviors, incorporate actual equipment

whenever it is cost effective to do so, and aim at consistency across models, simulations, and operations: per the present term of art, seamless simulation (Simulation Policy Study, 1990).

The study resulted in the formation of the Defense Models and Simulation Office (DMSO) within the office of the Director of Defense Research and Engineering to pursue seamless simulation.

DMSO aims at improving each of the three forms of tactical engagement simulation to support: (a) better training and operational rehearsal; (b) more informative operational tests and evaluations; (c) improved materiel acquisition; and (c) more reliable analyses for programming and budgeting. For improving virtual TES, DMSO's critical path is one of catalyzing development of simulations capable of handling 10^4 or more moveable entities. While DMSO recognizes that the order of magnitude of this goal is predicated upon some portion of that population representing dismounted combatants, the organization looks to the services primarily interested in these, the Army and the Marine Corps, to meet the technological challenge of inserting their warriors onto the virtual battlefield. Gorman (1991b) has proposed an "Individual Portal (I-Port)" as such a method for inserting individual dismounted combatants onto the virtual battlefield.

Research Development and Acquisition Applications of ICS

The Department of the Army now requires that all Army acquisition strategies for Acquisition Category I and II program will include a simulation support plan emphasizing the role of Modeling and Simulation (M&S) and Distributed Interactive Simulation (Office of the Assistant Secretary of the Army Research, Development and Acquisition, 1993). The Army Acquisition Executive can extend the same requirement to any other Army program at will. The prescribed Simulation Support Plan Outline mandates setting forth "constructive, live, or virtual M&S or DIS as applied to the requirements definition/analysis, engineering development, production, test and evaluation, logistics, training: how M&S and DIS has been or will be employed throughout the program by government and/or contractor activities." Additionally, the simulation support plan must be included in the Program Manager's briefing to the Army Secretarial Acquisition Review Council. Given the importance of dismounted combatants on any battalion-sized battlefield (e.g., infantry performing its mission and other soldiers manning shoulder-fired air defense weapons, anti-armor and anti-personnel weapons, controlling or designating for indirect fire weapons, observing, reporting, or emplacing or clearing obstacles), use of ICS seems imperative for collecting data on individual performances in battalion-scale combat. Therefore, development of ICS is another pacing event for

realistic simulation in support of Army materiel acquisition.

Conclusions

The foregoing leads to two conclusions. First, the utility of all models and simulations of war would be enhanced by ability to collect data on the behavior of dismounted combatants, preferably in real battle, but if not there, then in its closest approximation, TES. Second, the most promising form of TES for collecting behavioral data, virtual TES, is severely limited because of the present inability of the services to enable dismounted combatants individually to interact with a synthetic battle environment. There is, then, an urgent requirement for development of Individual Combat Simulations (ICS).

Purposes of ICS

This research effort focuses on three purposes or uses for ICS: (a) Combat Proficiency Training, (b) Mission Planning and Rehearsal, and (c) Mission Specific Training.

ICS for Combat Proficiency Training

In evaluating the effectiveness of possible ICS configurations, the end purpose should be held constantly in view. One important such purpose would be improved collective training in units. Individual combat skills, and even some teamwork can be developed within units using available part-task trainers, and existing forms of field exercises (which themselves should be understood as simulations of combat). But the costs of developing proficiency with tasks on the unit's Mission Essential Task List (METL) that would be impervious to the tumult and time-urgencies of large-scale, combined arms combat, and of building effective combined-arms teamwork within that environment, are high: opportunities to do so are rare, and will become the more so as resources for gaining and maintaining readiness are constrained. Such readiness is perishable, given the personnel turbulence common in some units. ICS should provide opportunities to gain and to maintain greater combat readiness per training dollar than other current collective training techniques. Advanced distributed simulation technology offers, moreover, ICS-ported access to battles being fought on virtual battlefields by other units. Thus, through cooperation, a unit commander could advance collective training for his individual combatants well beyond what he might within his own resources.

ICS for Mission Planning and Rehearsal

Current Army doctrine stresses the responsibility of a line unit commander for focusing training within his unit on directed or anticipated combat missions. Virtual TES could make it

possible to conduct collective training on tasks identified from actual contingency plans on terrain and against an opposing force comparable to what he expects to encounter should the plan be implemented. Hence, tasks, conditions, and standards could be precisely focused, and in conducting training per these, the commander could scrutinize and refine his plan, the better to exploit the capabilities of his personnel and his equipment. ICS would enable providing experience in implementing the plan for every individual combatant material to its success. By recording and providing feedback on individual performances in detail, ICS could lead to fine tuning of the plan.

Aspects of the plan that thus could be improved by virtual TES with ICS include the following:

Security. When the force for the Son Tay raid into North Vietnam was being readied, a replica of the objective compound was constructed for rehearsals, but for fear of detection by Soviet satellites, had to be dismantled each time one was expected overhead. The disaster at DESERT ONE in Iran was in part a function of failure to provide for rehearsal, dictated by concern that preparations for the operation would be detected by hostile intelligence or the news media. As in DESERT ONE, most operations involve units from the several services, positioned remote from one another. Virtual TES, particularly if encrypted and distributed, meets the requirement to insure that disparate team members understand their role, and can coordinate their operations.

Locus and Threat. Being able to plan with maps, photos, and other information concerning one location with intelligence concerning opposing forces there, makes possible the development of a plan that obviates or diminishes the need for reconnaissance and issuance of orders under fire, and leads to swift, sure execution of the mission. The commander, with virtual TES and ICS, can provide for dissemination of information to, and internalization by, every combatant.

Mission Definition. The unit commander can himself employ ICS, conceivably linked with the commanders of other units involved in the operation, to ascertain how best to accomplish his mission, and to anticipate contingencies.

Task Assignments. In the same manner, he can rehearse and refine his plan with his immediate subordinates, seeking to concert with them optimum timing and full employment of available resources.

Provisions for Robustness. Virtual TES inflicts "casualties," reflecting the reaction of the opposing force to the operations of the friendly. This feature focuses attention within the unit on the need for aggressiveness and initiative to

compensate for mission-essential personnel hors de combat. Especially in certain Special Operation Force undertakings, the entire purpose of an operation could hinge on performance of one pivotal individual task, so that availability of means, through ICS, for building the capacity to cope with the contingency of sudden loss of a key individual could endow the unit with robustness under fire, and higher assurance of mission accomplishment.

Logistics. Well-conducted virtual TES with ICS could make it possible to address issues of equipping and sustaining the individual combatant in the same fashion that the SIMNET form of virtual TES reveals logistical constraints on combat vehicles.

Communications, Command and Control. Particularly for dismounted combatants, command and control in battle is difficult. Synchronization of fires and maneuver, tactical sequencing, orchestration of medical evacuation and resupply, and avoidance of friendly fire incidents, all underwrite searching for those control mechanisms best suited to the operation at hand. Virtual TES with ICS would be far better than conferring over a map or a photograph, or pushing symbols around a sand-table.

Sustained Readiness. Military units rarely maintain homeostasis: promotions occur, leaves are granted, personnel rotate in or out, are sent off to school, get sick, or are subjected to disciplinary action. The longer the time between training for mission planning and rehearsal, and the execution of the plan, and the greater the number of plans for which the unit is responsible, the more the need for repetitive refurbishing of each plan, and the rehearsal of a unit's personnel for their role therein. Virtual TES with ICS offers a convenient means for accomplishing that rehearsal.

The result of careful mission planning and rehearsal would be not only competence, but also confidence within the unit that it could execute the plan.

ICS for Mission Specific Training

Whenever possible, training should continue right up to the point of mission execution. The value of such training increases as a unit draws closer to the time of execution. The third purpose of the ICS is thus to support such training, from the time the mission is assigned until the time of mission execution. The ICS will often be the only viable option available to the commander for conducting this training as the unit may already be at a staging at an airfield or on board ship, without access to field training sites. Moreover, ICS is particularly well suited to this purpose since it can quickly replicate the specific threat the unit will encounter on the actual terrain on which it

will fight. Rapid revisions can also be made to ICS training mission scenarios as last minute intelligence is received.

Virtual TES with ICS fits well the tense circumstances of a unit's pre-operational preparation. The overall commander of any operation being undertaken on short notice, like the Grenada rescue operation, or the Libyan air raid, would find distributed ICS an invaluable aid. Even when ample time is available for mission planning and rehearsal, as it was in instances during DESERT SHIELD/DESERT STORM, use of virtual TES with ICS would constitute insurance of thorough coordination despite last minute changes. New elements in the plan can be distributed vividly by the simulation, and the actions of each key participant can be honed within the context of the most current situation. With a transportable form of ICS readily amenable to update, units can be continuously trained right up to actual mission execution.

Individual Participants in Virtual Environments

Individual Combat Simulation (ICS) has been recognized as the next logical application of the virtual battlefield discovered and explored in SIMNET, and now designated to be the habitat of Close Combat Tactical Trainer (CCTT), Aviation Combined Arms Tactical Trainer (AVCATT), and Air Defense Combined Arms Tactical Trainer (ADCATT). The population of this battlefield by individual dismounted combatants is an essential step to permit the conduct of tactically realistic combined arms and special operations. But the successful projection of an individual soldier onto the virtual battlefield is much more demanding of both simulation art and science than providing portals (simulated vehicle windows) through which it can be passively experienced. The requirements to sense and manipulate virtual objects directly rather than to perceive and affect them through the mediation of an interposed representation of a crewstation presents real challenges.

During the past few years, research at various Government and academic laboratories has begun to provide tools for creating such an immersion experience. Focused primarily on development of novel human-computer interaction techniques and user interfaces for remote presence/teleoperator systems, these research activities have yielded both knowledge and specific devices facilitating the direct coupling of the human body to virtual environments. The experiments and concept demonstrations to date have been impressive in their implications of the power of future virtual environments into which humans can enter and interact. As a practical matter, however, those individual virtual environments created to date are universally deficient in terms of the richness of the cue environment and/or range and reactiveness of the response sensing mechanisms as useful substitutes for natural world alternatives.

ANALYSIS OF INDIVIDUAL COMBATANT SIMULATION CAPABILITIES

Approach

The initial step in analyzing the capabilities of virtual environments to support individual combatants was the determination of the behaviors that must be supported by the simulation The purpose was to: (a) identify the missions and collective tasks to be assessed; and (b) decompose the missions and tasks into their constituent elements that could then be related to simulation capabilities.

Selection of ARTEP Missions and Tasks

Missions and tasks were selected for screening from the following six ARTEPs:

Mission Training Plan for the Tank and Mechanized Infantry Battalion Task Force (ARTEP 71-2-MTP);

Mission Training Plan for the Tank and Mechanized Infantry Company and Company Team (ARTEP 71-1-MTP);

Mission Training Plan for the Infantry Rifle Platoon and Squad (ARTEP 7-8-MTP);

Battle Drills for the Infantry Rifle Platoon and Squad (ARTEP 7-8-DRILL);

Mission Training Plan for the Special Forces Company: Special Reconnaissance (ARTEP 31-807-31-MTP); and

Mission Training Plan for the Special Forces Company: Direct Action (ARTEP 31-807-32-MTP).

Each infantry ARTEP contains a Mission-to-Collective Task matrix that lists the missions covered by the ARTEP and indicates the ARTEP Tasks they encompass. The tasks are grouped within the battlefield operating systems (maneuver, fire support, air defense, command and control, intelligence, mobility and countermobility, and combat service support) applicable to the ARTEP. A typical infantry Mission-to-Collective Task matrix, with illustrative tasks within each battlefield operating system category applicable to that ARTEP, is depicted in Table 1.

Table 1 Illustrative Mission-to-Collective Task Matrix (from 7-8-MTP)

	Missions						
Collective Tasks	Movement To Contact	Attack	Raid	Ambush	Recon/ Security	Defend	Retrograde
Maneuver							
Assault	x	x	x			x	x
Overwatch/Support by Fire	x	x	x			x	x
Fire Support							
Employ Fire Support	x	x	x	x	x	x	x
Mobility and Survivability							
Breach Obstacle	x	x	x				
Perform Helicopter Movement	x	x	x	x	x	x	x
Air Defense							
Defend Against Air Attack	x	x	x	x		x	x
Combat Service Support							
Perform Aerial Resupply	x	x	x	x	x	x	x
Perform Vehicle Operations	x	x		x	x	x	x
Command and Control							
Prepare for Combat	x	x	x	x	x	x	x
Consolidate and Reorganize	x	x	x	x	x	x	x

The ARTEP also contains a training and evaluation outline for each of the Tasks listed in the Mission-to-Collective Task matrix. An illustrative training and evaluation outline, with 2 of its 3 Subtasks, is depicted in Table 2. Note that the echelon(s) to which the task applies is listed at the top of the training and evaluation outline.

The ARTEPs for Special Forces units differ slightly in that each Special Forces ARTEP addresses a separate mission, and as such, they contain a Sub Mission-to-Collective Task matrix rather than a Mission-to-Collective Task matrix. To maintain data consistency, these sub missions are considered missions within this research effort.

The infantry ARTEP-DRILL book lists drills rather than tasks, and does not contain a Mission-to-Collective task matrix since the majority of the drills are mission independent. For

the purposes of this research effort, each drill is considered to be a task, and Mission-to-Collective Task matrices have been developed to relate them to the Infantry and Special Forces missions.

Tasks were selected from the ARTEPs for assessment if they: (a) applied to an infantry platoon/squad or squad, or the special forces A/B team or A team; (b) involved dismounted operations; (c) were unclassified; and (d) were generally applicable to virtual environments.

Table 2 Illustrative Training and Evaluation Outline (from ARTEP 7-8-MTP)

ELEMENT: PLATOON/SQUAD
TASK: ASSAULT (7-3/4-1011) (FM 7-7) (FM 7-7J) (FM 7-70)

ITERATION 1 2 3 4 5 (circle)

TRAINING STATUS T P U (circle)

CONDITIONS: An enemy squad has occupied defensive positions or is moving to the platoon front. The enemy has indirect fire and CAS capabilities. The platoon is operating separately or as part of a larger unit. The platoon is directed to attack the enemy. Plans, preparation, and movement to the objective have been accomplished.

TASK STANDARD:

1. The platoon main body is not surprised or fixed by the enemy.
2. The platoon sustains no more than 20 percent casualties.
3. The platoon accomplishes its assigned task within the commander's intent. The platoon kills, captures, or forces the withdrawal of 100 percent of the enemy.
4. The platoon sustains no casualties from friendly fire.
5. The platoon sustains no more than one vehicle loss (platoon echelon only).

SUBTASKS AND STANDARDS: GO NO-GO

*1. The platoon leader organizes the platoon for the assault (See Appendix A, Tactical Technique A-1.)
  a. Designates an assault element consisting of one, two, or all squads (dependent on the platoon acting alone or as part of a larger unit.

  b. Designates a support element consisting of one or two squads. (See T&EO 7-3/4-1007, Overwatch/ Support by Fire.)
  c. Vehicle commanders move vehicles into covered and concealed positions.
  d. Dismount teams dismount.

2. The platoon positions for the assault.
  a. The platoon leader designates a support position and a primary direction of fire to the support element leader. (See T&EO 7-3/4-1007, Overwatch/Support by Fire.)
  b. The support element delivers continuous, well-aimed fire with enough volume to suppress the enemy. (See Appendix A, Tactical Technique A-1.)
  c. Under the platoon leader's control, the assault element moves to the last covered and concealed position before the assault.
  d. The assault element uses smoke (if available) to cover its movement.
  e. The assault element moves without masking the support element's suppressive fires.
  f. The platoon leader or platoon FO calls for preparatory smoke or indirect fire (if available) on the objective before assault.
  g. The platoon leader ensures all elements are in position before the assault.

*Leader task

With regard to the final consideration, special forces tasks performed within a secure environment outside the area of tactical operations were not selected. These tasks are performed in a fixed facility and primarily involve the use of wall-mounted maps and charts, written and verbal reports, communication systems, and reference manuals. They can be readily performed within any room or office equipped with the items listed above, and are therefore not cost effectively supported by the more expensive virtual environment training alternative.

Of the six ARTEPs initially selected for review, the two that address the battalion task force (ARTEP 71-2-MTP) and the company team (ARTEP 71-1-MTP) were not selected for further analysis as they do not address squad or team performance. Table 3 summarizes the number of tasks that were selected for further analysis from each of the three remaining ARTEPs.

Table 3 Summary of Tasks Selected from ARTEPs

ARTEP Number	ARTEP Name	Tasks Selected For Analysis	Tasks Eliminated from Further Analysis
ARTEP 7-8-MTP	Mission Training Plan for the Infantry Rifle Platoon and Squad	37	11
ARTEP 7-8-DRILL	Battle Drills for the Infantry Rifle Platoon and Squad	8	14
ARTEP 31-807-31-MTP	Mission Training Plan for the Special Forces Company: Special Reconnaissance	20*	16*
ARTEP 31-807-32-MTP	Mission Training Plan for the Special Forces Company: Direct Action	22	18
	Total Number of Unique Tasks	**67**	**43**

Table 4 Tasks of Individual Combatants Selected for Analysis

1	Assault	24	Breach Obstacle	46	Operate in NBC Environ.
2	Overwatch	25	Helicopter Movement	47	Chem / Bio Decontamination
3	Disengage	26	Boat Movement	48	Radiological Decontamination
4	Knock Out Bunker	27	Prepare for Chem. Attack	49	Infiltrate Area by Land
5	Clear Trench Line	28	Prepare for Nuc. Attack	50	Establish Contact w/ Asset
6	Antiarmor Ambush	29	Cross Chem. Cont. Area	51	Move in Denied Area
7	Hasty Ambush	30	Cross Nucl. Cont. Area	52	Estab. Mission Support Site
8	Point Ambush	31	Cross Water Obstacle	53	Establish Surveillance Site
9	Defend	32	Maintain Op. Security	54	Send Information by Radio
10	Occupy Assembly Area	33	Defend - Air Attack	55	Prepare for Exfiltration
11	Move Tactically	34	Aerial Resupply	56	Exfiltrate by Land
12	Cross Danger Area	35	Sustain	57	Exfiltrate by Water
13	Passage of Lines	36	Prepare for Combat	58	Exfiltrate by Air
14	Clear Wood Line	37	Consolidate & Reorganize	59	Confirm Operation Plan
15	Occupy Obj. Rally Pt.	38	Infiltrate by Air	60	Interdict a Target
16	Occupy Patrol Base	39	Infitrate by Water	61	Conduct Recovery Ops.
17	Clear Building	40	Conduct Assembly	62	React to Contact
18	Defend Built-up Area	41	Control Info Dissemination	63	Break Contact
19	Stay Behind	42	Employ Countermeasures	64	React to Ambush
20	Linkup	43	Prepare for NBC Operations	65	React to Indirect Fire
21	Infiltrate/Exfiltrate	44	React to Chem or Bio Attack	66	React to Chemical Attack
22	Reconnoiter Area	45	React to Nuclear Strike	67	React to Nuclear Attack
23	Occupy OP/Surveil				

Decomposition of ARTEP Tasks

The importance of decomposing the missions and tasks down to the lowest level of constituent behaviors was identified during the ARI Fort Knox Field Unit's research program on Unit Performance Measurement and Training Program Design for Networked Simulation (SIMNET) (White, McMeel, & Gross, 1990; Madden, 1991). During that research effort, the assessment of the capability of SIMNET to support a collective task was found to be dependent

upon the ability to support the behaviors associated with each of the standards prescribed for the task. This was due to the fact that in almost every case, the task defined a behavior that was too broad to serve as a basis for quantifying the precise simulation capabilities or requirements involved.

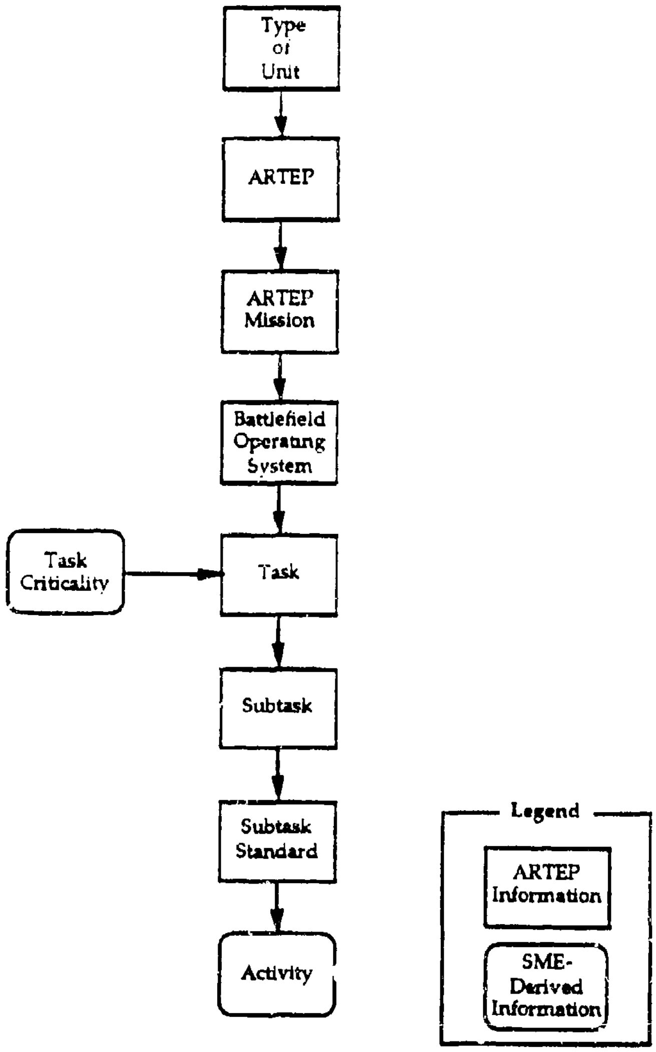

Figure 1. Decomposition of an ARTEP task.

Table 5 Illustrative Examples of Individual Combatant Activities

Task	Subtask	Subtask Standard	Activity
Assault	1. The platoon leader organizes the platoon for the assault.	a. Designates an assault element consisting of one, two, or all squads.	Point to squad or individual. See individual pointing at self or own unit. Give verbal orders Hear orders
Disengage	1. The dismounted platoon (squad) disengages while moving	The platoon (squad) members move for the distance and in the direction ordered	Move upright, tactically Move in accordance with directions Calculate distance moved

As illustrated in Figure 1, an ARTEP is a hierarchical set of behaviors performed by a unit, starting with a mission, progressing through tasks, and ending with subtask standards at the smallest unit of behavior that is described in the ARTEP. Each of the ARTEP tasks selected during the foregoing assessment was analyzed by a military expert to identify the fundamental behaviors, hereafter referred to as "Activities." This analysis was performed at the Subtask Standard level (see Table 2 above). Typical outcomes of this analysis are listed in Table 5.

Duplicate activity descriptions were eliminated, and a total of 292 unique activities were identified that described the elemental behaviors of dismounted combatants. To further focus the analysis, the list of activities was analyzed for appropriateness virtual environment training. Forty activities were eliminated from further consideration because they involved: (a) ingesting food or drink; (b) performing personal hygiene; (c) donning or removing clothing; or (d) too much force feedback to be practical. The 252 unique activities that describe the elemental behaviors of dismounted combatants that were retained for further analysis are listed in Table 6.

Table 6 Activities of Individual Combatants

1	Give verbal orders	85	Steer a boat	169	Mark mine
2	Use password	86	Identify bushes	170	Move bent over (when approaching helicopters)
3	Blow whistle for signal	87	Move upright, tactically	171	Place filters on flashlight
4	Call in preplanned fire requests	88	Idendify covered and concealed route	172	Write report on supply status
5	Inspect for correct "soldier's load"	89	Identify actual squad members	173	Check proper wearing of protective suit
6	Hear orders	90	Move upright, reconnoiter	174	Employ probes (for mines)
7	Operate radio or telephone	91	Identify assigned sectors	175	Identify jet aircraft
8	Identify safe and danger area	92	Inspect Equipment	176	Inspect boats
9	Perceive relative position of other units	93	Distribute supplies and equipment	177	Position antitank mines
10	Give hand and arm signals	94	Estimate distance from self to a distant point	178	Draw charts and diagrams
11	Move in accordance with directions	95	Read charts and diagrams	179	Draw range card
12	Visually search for enemy	96	Move by rush	180	Enter bunker through rear entrance
13	Identify hand and arm signals	97	Identify enemy soldiers	181	Guide squad and squad members
14	Aim and fire individual weapon	98	Record observation notes	182	Hang camouflage net
15	Aim and fire crew served weapon	99	Operate chemical-alarm	183	Identify boat obstacles or hazards
16	Aim and fire M60 MG	100	Identify restricted fire lines, check points, etc.	184	Identify shadows
17	Aim and fire M203 GL	101	Move with stealth	185	Move during limited visibility
18	Identify support position which will enable fire to be placed on enemy	102	Identify activity of personnel	186	Use tug line
19	Maintain position relative to other personnel	103	Check radio instruments	187	Assemble crossing equipment. (ropes & ponchos)
20	Read standard military symbols on a map	104	Read written order	188	Discern own rate of movement
21	Identify overwatch position	105	Identify actual chain of command	189	Draw control features on map
22	Identify areas that mask supporting element fires	106	Administer first aid	190	Identify overhanging branches

Table 6 Activities of Individual Combatants (cont'd)

23	Perceive relative position of weapon fire	107	Carry protective mask	191	Identify puddles
24	Change rate of fire	108	Position/sight weapons	192	Mark taut trip wire
25	Fire flare to signal	109	Move upright rapidly, tactically	193	Mark weapon position
26	Aim and fire LAW	110	Prepare demolitions	194	Move by high crawl
27	Identify obstacles	111	Count members of the squad	195	Sit in vehicle
28	Place crew served weapons in operation	112	Follow route designated on map	196	Inspect condition of feet
29	Identify dead space	113	Identify civilians	197	Determine location of flying aircraft
30	Identify light-reflected from shiny objects	114	Identify enemy voices	198	Estimate distance to flying aircraft
31	Arm hand grenade	115	Throw smoke grenade	199	Lay wire along final protective fire line
32	Identify firing positions in urban area	116	Set up early warning (trip wire) devices	200	Determine if rivers and streams are fordable
33	Aim, fire, and track DRAGON	117	Attach telephone to commo wire	201	Identify hand and arm signals with night vision devices
34	Discern location within an area	118	Dismount vehicle	202	Secure boat
35	Read dosimeter scale	119	Move upright in built-up area, tactically	203	Burn garbage and waste
36	Set frequency on radio	120	Operate flashlight	204	Calculate distance moved (pacing and offsets)
37	Identify glow from cigarette	121	Set up and employ Claymore mines	205	Conduct NBC surveys
38	Hear own movement noise	122	Identify firing positions in natural terrain	206	Identify a stroke (paddling rate)
39	Read CEOIs	123	Identify squad voices	207	Use NBC equipment to conduct surveys
40	Identify firing positions in building	124	Mark routes	208	Feel tug on tug line
41	Identify orientation of soldier's weapon or fire	125	Discern map coordinates of desired location for indirect fire	209	Identify a sleeping soldier
42	Identify flashes from enemy weapons	126	Enter and exit rubber boat	210	Identify trash on the ground
43	Engage aircraft with small arms	127	Cook off grenade	211	Read a map

Table 6 Activities of Individual Combatants (cont'd)

44	Camouflage self (to include face)	128	Throw "cooked off" grenade	212	Perform chemical decontamination
45	Fill rifle magazines	129	Identify damage to equipment	213	Identify camouflaged individual
46	Walk fire across the objective	130	Throw grenade	214	Remove signs of presence
47	Identify orientation of main guns on vehicles	131	Determine own location on map with respect to control measures	215	Move to a location on a map
48	Discern direction enemy is moving	132	Lay, sight, and arm Claymore mine	216	Construct fighting position with overhead cover
49	Place LAW in operation	133	Repair equipment	217	Activate demolitions
50	Prepare DRAGON sight	134	Enter trench	218	Establish cache
51	Read watch to tell time	135	Exit from aircraft	219	Camouflage fighting position
52	Use night vision devices	136	Kill a soldier with a weapon	220	Waterproof water-sensitive items
53	Determine azimuth and direction to distant object	137	Avoid kicking up dust	221	Dig hasty fighting position
54	Identify orientation of soldier's body	138	Mark LZ/DZ	222	Camouflage trail after passing
55	Shift fires	139	Read Unit SOP	223	Remove debris from LZ
56	Count/inventory expendable supplies	140	Record dosimeter readings	224	Perform radiological decontamination
57	Discern own movement direction	141	Write report on equipment status	225	Clear an objective
58	Identify rear of armored vehicle	142	Discriminate between friendly and enemy aircraft	226	Remove or tape items which may reflect light
59	Identify approach to LZ/DZ which is free of tall trees, etc.	143	Climb on and enter vehicle	227	Hear covered and concealed firing positions
60	Identify distribution points for supplies	144	Enter and sit down in aircraft	228	Lay commo wire
61	Orient map to field of view	145	Enter door, window, hole	229	Cover all reflective surfaces
62	Place weapons on safe	146	Position chemical alarm	230	Employ smoke pots
63	Follow azimuth	147	Throw grenade through entrance to bunker	231	Construct obstacle
64	Identify armored vehicle blind spots	148	Destroy equipment	232	Hear relative position of noise

Table 6 Activities of Individual Combatants (cont'd)

65	Identify LZ	149	Estimate distances between two remote points	233	Identify good water crossing site
66	Identify orientation of soldier's field of view	150	Activate early warning (trip wire) devices	234	Lay wire
67	Perceive relative position of lights	151	Clear obstacles	235	Camouflage boat
68	Identify side of tank	152	Mark cleared bunker or trench	236	Inject Atropine
69	Identify slopes which must be climbed	153	Move by low crawl	237	Clear fields of fire
70	Identify steep slopes	154	Read markings on vehicles	238	Activate a landmine
71	Use binoculars	155	Set up tug line (Trip Wire)	239	Employ demolitions to breach mines
72	Use compass to determine azimuth readings	156	Use switchboard	240	Feel heat and shock of blast wave
73	Determine direction distant aircraft is flying	157	Write an NBC report	241	Hear location of impact point of indirect fire based on sound
74	Inspect boat landing	158	Write report on personnel strength	242	Identify dug in fighting position
75	Bend radio antenna down	159	Move through a building with sensing of where its front is	243	Place wire mesh over windows
76	Identify blind side of bunker	160	Feel for pressure probes and trip wires	244	Blow holes in wall
77	Identify bunker	161	Measure percent slope	245	Identify extent of injury to soldier
78	Test fire weapons	162	Crawl	246	Identify type of injury to a soldier
79	Visually search for aircraft	163	Cut slack trip wires	247	Evacuate casualties
80	Count ammunition	164	Draw sector sketch	248	Search, gag, and tag POWs
81	Identify ranks	165	Identify slopes which can only be climbed with difficulty	249	Navigate while afloat
82	Mark vehicles	166	Identify slopes which cannot be climbed	250	Kill a soldier with hands
83	Smell smoke from cigarettes	167	Mark cleared room	251	Hear ORP locations which are easy to defend for a short time
84	Identify entrance to bunker	168	Mark lanes through minefield	252	Construct 1 or 2 rope bridge

IDENTIFICATION OF SCIENTIFIC LITERATURE AND RESEARCH NEEDS

Using the information provided in the analysis of ARTEP tasks, the identification of related scientific literature and the remaining research needs was achieved in a series of steps illustrated in Figure 2.

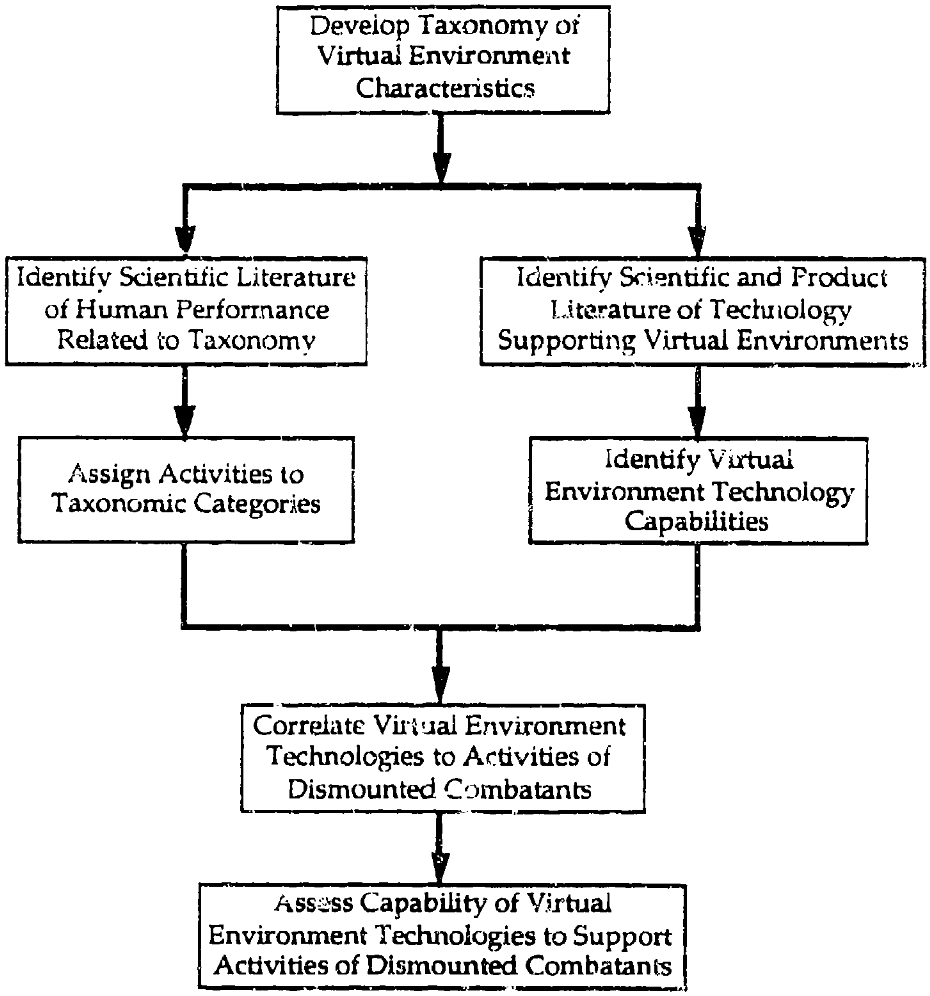

Figure 2. Steps in assessing capabilities of virtual environment technologies to support activities of dismounted combatants.

Taxonomy Development

Step one began with the iterative development of a taxonomy, using both behavioral scientists at Illusion Engineering and virtual environment technology experts at the Human Interface Technology Laboratory of the University of Washington. This

taxonomy, illustrated in summary form in Table 7, outlines the different aspects of a virtual environment training system, providing the framework necessary to correlate human characteristics with technological parameters.

Table 7 Summary of the Virtual Environment Taxonomy

1	**Behavioral Considerations – Input**
1.1	Visual Modality
1.1.1	Image Quality
1.1.2	Visual Target Acquisition
1.2	Auditory Modality
1.2.1	Non-Speech Signals
1.2.2	Speech Signals
1.2.3	Acoustic Target Acquisition
1.3	Vestibular Modality
1.3.1	Angular Acceleration
1.3.2	Linear Acceleration
1.3.3	Body Rotation
1.3.4	Adaptation
1.3.5	Vibration
1.4	Proprioception
1.4.1	Gross Motor Movement
1.4.2	Fine Motor Movement
1.5	Cutaneous (Tactile) Modality
1.5.1	Cutaneous Sensitivity
1.5.2	Pattern Discrimination
1.5.3	Thermal Sensitivity
1.5.4	Force Feedback Considerations
1.6	Olfactory Modality
1.6.1	Sensitivity (Detection)
1.6.2	Location/Orientation Discrimination
2	**Behavioral Considerations – Output**
2.1	Speech
2.1.1	Continuous/Discrete
2.1.2	Vocabulary Size
2.1.3	Speaker Dependence
2.1.4	Background Noise Sensitivity
2.2	Position and Orientation
2.2.1	Psychomotor Movement

Table 7 Summary of the Virtual Environment Taxonomy (cont'd)

3	**Technology Approaches**
3.1	Interactive Displays
3.1.1	Visual Display
3.1.2	Acoustic Display
3.1.3	Tactile Display
3.1.4	Force Feedback Display
3.1.5	Olfactory Display
3.1.6	Kinesthetic/Proprioceptive Display
3.2	Behavioral Effectors (Physical or Virtual Objects That Simulate Objects Used In Tasks)
3.2.1	Psychomotor Movement Sensing
3.2.2	Instrumented Objects (E.G. Rifle, Grenade, Knife)
4	**Technology Considerations** (linked to technology approach)
4.1	Interactive Display Factors
4.1.1	Factors Affecting the Ability to See the Display
4.1.2	Factors Affecting the Ability to See the Outside World
4.2	INTERACTIVE Auditory Display Factors
4.2.1	Factors Affecting the Ability to Hear A Sound
4.2.2	Factors Affecting the Ability to Hear the Outside World
4.3	Interactive Tactile Display Factors
4.3.1	Factors Affecting the Ability to Feel A Display
4.3.2	Factors Affecting the Ability to Feel the Outside World
4.4	Interactive Force Feedback Display Factors
4.4.1	Spatial Factors
4.4.2	Resistance Generation
4.4.3	Temporal Factors
4.4.4	Tactile Model Stabilization Factors
4.5	Interactive Olfactory Display Factors
4.5.1	Factors Affecting the Ability to Acquire Olfactory Information
4.5.2	Factors Affecting the Ability to Smell the Outside World
4.5.3	Intensity of Outside Scents
4.6	Multiple Modality Display Factors
4.6.1	Intermodal Interference
4.6.2	Intermodal Synergy
4.6.3	Intermodal Correlation
4.6.4	Interstimulus Temporal Factors (E.G. Delays Between Presentation to Different Sensory End-Organs)
4.6.5	Interstimulus Spatial Factors
4.7	Artifacts
4.7.1	Effects of Encumbrances
4.8	Behavior Transducer Factors

The first two sections of the taxonomy address the behavioral aspects of such a training system. Section one is a breakdown of the sensory input characteristics of a human, such as the visual imaging properties of the eye, the acoustic imaging properties of the ear, the ability to perceive posture and orientation of the body, and the perceptual qualities of the skin. Section two of the taxonomy classifies the output characteristics of the human -- the speech and motor abilities that allow people to affect the (virtual) environment. The remaining two sections of the taxonomy address the technology involved in a virtual environment training system. Section three lists technological approaches for engaging the sensory and psychomotor modalities, while section four enumerates the technological performance parameters. The complete Virtual Environment Taxonomy is shown in Appendix A.

Identification of Human Performance Literature

The primary reference book used for the behavioral taxonomy regarding perception, cognition, and human information processing was the *Handbook of Perception and Human Performance* (Boff, Kaufman, and Thomas, 1986) and the companion volume: *User's Guide - Engineering Data Compendium: Human Perception and Performance* (Boff and Lincoln, 1988). Additional primary references from which antecedent sources were sought included the *Cumulative Index to Human Factors*, 3rd edition (Human Factors Society, 1986), covering the years 1958 through 1985, and its supplement covering the years 1986 through 1990 (Human Factors Society, 1991), the books *Engineering Psychology and Human Performance* (Wickens, 1984), *Perception* (Matlin, 1983), *Human Factors in Engineering and Design* (Sanders and McCormick, 1987), the *Human Engineering Guide to Equipment Design* (Morgan, Cook, Chapanis, and Lund,1963), the *Human Engineering Guide to Equipment Design* (VanCott and Kinkade, 1972) and *Physiology of Behavior* (Carlson, 1981). References related to human behaviors have been mapped to their associated subcategory in the taxonomy, shown as Appendix B, Human Performance Bibliography.

As in any multi-disciplinary search, there was some overlap in the literature retrieval. This was considered a necessary drawback, to achieve a comprehensive search. Duplications with the later technology search were deleted.

Assignment of Activities to Taxonomy

To assign the activities selected for further analysis (shown previously in Table 6), each activity was analyzed in terms of the behavioral considerations as defined in the taxonomy (i.e., each activity was matched with the suitable subsections of the taxonomy). This analytic process was divided between behavioral scientists and virtual environment technologists, as

appropriate. For example, both the behavioral scientists and virtual environment technologists considered the activity "Use Password." This activity included only the category "Speech Output" from the taxonomy. On the other hand, the activity "Carry Protective Mask" included the following categories from the taxonomy:

Fine Motor Movement
Cutaneous Sensitivity
Pattern Discrimination
Force Feedback Considerations
Hand Movement
Finger Movement and
Body Movement

The analysis undertaken in this step was supported by the human performance literature identified in the previous step.

Identification of VE Technology Literature

References related to technology were derived in a series of computer-assisted processes. Important journals, conference proceedings and products that were too current to be indexed either in print or electronically, were inserted into the bibliographies manually. The literature search was performed incrementally as new sources of information were identified. Keying on basic VR hardware terminology was the most effective means of searching the on-line databases. For example, searching under HMD, Head Mounted Displays, Eyephones, and other technology synonyms retrieved the relevant hits for the knowledge base. Classification codes were used when available. INSPEC and COMPENDEX both provide a thesaurus of terms to look under, for example: Computer Graphics and (3-D or 3-Dimensional). Important researchers were searched for both by name and sponsoring institute to retrieve a comprehensive listing of their research. The on-line search was performed using the following databases:

NTIS: The NTIS database consists of government sponsored research, development, and engineering reports plus journal articles, reports and translations prepared by federal agencies, their contractors or grantees. The on-line database includes citations from 1964 to the present, updated biweekly.

INSPEC: INSPEC is the database for Physics, Electronics and Computing. This database corresponds to the three Science Abstracts print publications: Physics Abstracts, Electric and Electronics Abstracts, and *Computer and Control Abstracts*. covering research from 1983 to the present, updated bi-monthly.

COMPENDEX Plus: This database provides international coverage of significant engineering and technological literature. COMPENDEX Plus corresponds to the printed publication Engineering

Index, plus additional conference records from the Engineering Meetings file. COMPENDEX Plus is updated monthly, and covers engineering research from 1970 to present.

Aerospace Database: The Aerospace Database is produced by the American Institute of Aeronautics and Astronautics/Technical Information Service (AIAA/TIS), New York, NY. The Aerospace Database supports basic and applied research in aeronautics, astronautics, and space sciences, as well as technology development and applications in supporting fields such as physics, communications and electronics. The database coverage is from 1962 to the present, updated twice a month.

MATHSCI: This database covers international research literature in mathematics, computer science, and statistics, and applications in areas such as physics, engineering, and information systems. MATHSCI has seven subfiles on-line, representing the print counterparts: Mathematical Reviews and Current Mathematical Publications, produced by the American Mathematical Society; ACM Guide to Computing Literature and Computing Reviews , published by the Association for Computing Machinery (ACM); Technical Reports in Computer Science, compiled by Stanford University; Current Index to Statistics, published by the American Statistical Association and Institute of Mathematical Statistics; and Index to Statistics and Probability (Tukey), by Tukey and Ross. The database covers the literature from 1959 to the present and is updated monthly.

JapanTechnology: JapanTechnology is an important source for the latest developments in Japanese research, technology and business. The database covers over 500 Japanese journals, from 1985 to the present, updated monthly.

SUPERTECH: This database contains important coverage of the robotics, CAD/CAM, and artificial intelligence aspects of virtual environment research. SUPERTECH consists of five sub-files indexing the monthly abstracting journals: Artificial Intelligence Abstracts, CAD/CAM Abstracts, and *Robomatix Reporter*. The coverage is from 1973 to the present for Robotics and 1984 to the present for Artificial Intelligence and CAD/CAM; SUPERTECH is updated monthly.

Various newsletters and trade literature were obtained and screened for up-to-date additions to the growing VR technology. The newsletters include: *CyberEdge Journal*, 928 Greenhill Road, Mill Valley, CA 94941-3406; *Virtual Reality Report*, Meckler Corporation, 11 Ferry Lane West, Westport, CT 06880; and *Virtual Reality News*, 38640 Oakbrook Road, Farmington Hills, MI 48331.

Identification of VE Technology Capabilities

The next step involved identifying the capabilities of virtual environment technologies to support visual, auditory, tactile, force-feedback and chemical requirements. Kinesthetics, proprioception, and the vestibular modality are included under force feedback since the requirement definitions are essentially the same. A list of five levels of technology sophistication for each approach identified in section three of the taxonomy (Technology Approaches) was developed. These levels represent the estimated time in which the virtual environment technologies will be available to support the various behaviors required. There is an implicit date of expected availability but this will be affected by the amount of investment in a particular technology area. The following estimates of time can be made, but they are without the benefit of an investment strategy:

Performance Level	Availability of Technology
1 = low	6 months
2 = low to medium	12 - 18 months
3 = medium	18 - 30 months
4 = medium to high	30 - 42 months
5 = high	unknown

The virtual environment technologists of the Human Interface Laboratory used their experience in the industry, and the information retrieved from the technology review, to identify these technology capabilities, shown in Table 8.

:ble 8 Virtual Environment Technology Capabilities

Performance Level	Vision	Acoustic	Tactile	Force Feedback	Olfactory
1 - Low	Monocular narrow field-of-view inclusive or see-through display ~20 degrees IFOV 300H X 200V pixels 1000 polygons	Speaker dependent recognition of 50 single utterances Individual speakers to create sound	Simple single bladder arrangement for tactile display	No force feedback	No olfactory
2 - Low to Medium	Monocular medium FOV display inclusive or see-through 40-50 degree IFOV VGA pixel count 5000 polygons	Speaker dependent phrase recognition of 200 utterances Generic Head-Related Transfer Function (HRTF) for 3D sound	Simple bladder tactile feedback display (one per finger)	No force feedback	No olfactory
3 - Medium	Medium field-of-view binocular inclusive or see-through display 60-80 degrees IFOV 800 X 800 pixels 20,000 polygons	Speaker dependent recognition of 1000 utterances Speaker independent recognition of 50 utterances 3D sound with individual HRTF	Spatial Tactile display with 10 x 10 elements	Simple hand constraint (with bladders?) for force feedback Head, hand, finger, body movement input, instrumented objects with 6 d.o.f.	No olfactory
4 - Medium to High	100-120 IFOV 1200 X 1200 pixels 100,000 polygon,	Speaker dependent, connected speech, 5000 vocabulary 500 speaker dependent Multiple channel 3D sound with echo, ambiance	200 X 200 elements	Force feedback to hand and arms using active viscosity materials to constrain movement	Olfactory display for 20 odors (vials)
5 - High	120 + IFOV display within spherical field-of-regard 4000 X 3000 pixels 500,000+ polygon count	Speaker independent connected speech, 5000 vocabulary 3D sound with individual HRTF, including echo, ambiance, 100 channels	Variable resolutions for finger and hand	Force feedback bodysuit using active viscosity materials	Olfactory display with real time chemical synthesis - 100 odors

Correlation of VE Technologies to Activities

In the next step, the levels of technology sophistication were then correlated to the individual "Activities" and the associated "Taxonomy Categories", resulting in the finished product entitled "Technology Performance Requirements for Individual Combatant Activities", shown in Appendix C. To accomplish this, two independent analyses were performed by behavioral psychologists (one Ph.D. Engineering Psychologist and one M.A. Human Factors Psychologist). A discussion between these two psychologists resolved any discrepancies that occurred. The analysis involved addressing each behavioral requirement for each individual Activity as to the minimum technological capability necessary to adequately perform the particular Activity in a virtual environment.

These "Performance Requirement" assessments represent the last column in Appendix C. For example, the Activity "Use password" only requires speech output. Since the number of possible words used in the Activity "Use password" is minimal, a speech output device capable of only 50 single utterances in a speaker dependent system (Category 1 - Low) was judged to be all that is necessary to support this Activity. The Activity "Give verbal orders" also requires speech output. The performance of this Activity, however, requires an extensive speech output system and therefore the technological capability assessment is Category 4 -Medium to High.

Assessment of VE Technology to Support Activities

An objective of the current effort was to develop a relationship between the activities performed by individual dismounted combatants, and the estimated ability of current and projected technology to support the performance of these activities individually and in aggregate in the virtual environment. A panel of virtual interface technology specialists consisting of faculty, staff, and graduate students at the Human Interface Technology Laboratory at the University of Washington was assembled. The panel used their own experience regarding virtual interface technology and knowledge of the literature to make the assessments. The technology performance levels discussed above were used as the primary criteria for assessing the "Availability of Technology" for achieving a useful virtual simulation for a specific training activity.

The transfer assessment was made using the following criteria:

the primary sensory and effector modalities that would be used to perform the real task;

the projected performance of the virtual simulation

subsystems including the degree of difficulty of achieving fidelity and realism in a simulated or virtual task using the primary and secondary modalities;

the likelihood that virtual simulation artifacts may affect a negative transfer of training (e.g. simulator response latencies, visual resolution, effect of generic head-related transfer function on the localization of sound for an individual user).

Appendix D presents the list of 252 Activities selected for study. For each Activity, the appendix presents the research team's estimates of the following attributes:

Technology Requirements. Detailed ratings of the level of performance required by visual, acoustic, tactile, force feedback, olfactory, and kinesthetic cueing systems as appropriate to support each activity, with the following rankings:

1 = Very low difficulty (can use existing technology)
2 = Low to medium difficulty (can use existing technology with modification and integration)
3 = Medium difficulty (will require development of some new technology)
4 = Medium to high difficulty (will require substantial development of new technology)
5 = Very high difficulty (will require a breakthrough in technology to achieve)

Sensory Mode. An assessment of the primary and secondary cueing and response modalities required to perform the activity, with the following coding:

S = Sound
V = Vision
T = Tactile
F = Force feedback

Transfer Effectiveness. An estimate of the transfer effectiveness of a virtual environment-based training intervention based upon our review of the behavioral and technical literature and experience with similar skill training problems in virtual environments, with the following rankings:

5 = Completely applicable and desirable in terms of cost/effectiveness
4 = Fair applicability
3 = Marginal applicability
2 = Probably can be done but very low cost/effectiveness
1 = No training effectiveness
0 = Uncertain applicability

The data analyzed herein represent qualitative ratings by expert evaluators. To the best of our judgment as researchers, the data are complete, and fairly and accurately present these experts' opinions.

Summary of Activity Ratings

Two criteria have been applied at the activity level to the listing to identify those tasks deserving of particular attention. First, those activities for which the technical challenges appear to be particularly significant (availability of technology rating of 4 or 5) are highlighted. Also highlighted are those activities that in the opinion of experts are unlikely to provide effective training transfer when practiced individually in a virtual environment. Of the total of 252 activities, 101 are projected to provide marginal transfer (ratings of 1 or 2). There are a total of 46 technically challenging activities (ratings 4 or 5). Among these, 15 are also expected to transfer poorly and should to be eliminated from near term consideration in the research effort.

Of the 546 total Subtasks, each comprised of one or more Activities, 29.9% are noted to be particularly technically challenging, 52.9% include one or more low transfer activities, while the remaining 17.2% are judged to be technically achievable and worthwhile from a transfer standpoint.

Among Activities noteworthy because of the combination of technical challenge and virtual environment transfer potential are three Activities with low transfer ratings (1) and high difficulty ratings (5). These tasks are "Inspect condition of feet", "Kill a soldier with hands", and "Search gag, and tag POW's." These are probably not reasonable short or mid-term developmental targets.

Slightly higher in expected transfer level, but still posing very high developmental difficulty are the activities shown in Table 9.

Table 9 Activities with Medium Transfer and High Difficulty

Activity	Transfer	Difficulty
Camouflage boat	2	4
Camouflage fighting position	2	4
Camouflage trail after passing	2	4
Cover all reflective surfaces	2	4
Inject Atropine	2	4
Place wire mesh over windows	2	4
Remove debris from LZ	2	4
Remove or tape items that may reflect light	2	4
Remove signs of presence	2	4
Waterproof water-sensitive items	2	4
Evacuate casualties	2	5
Navigate while afloat	2	5

In the other extreme of the transfer domain, the activities shown in Table 10 would be expected to transfer well from the virtual to the actual environment, but pose serious technical challenges. This group should be addressed over the longer term.

Table 10 Activities with High Transfer and High Difficulty

Activity	Transfer	Difficulty
Activate a land mine	4	4
Blow holes in wall	4	4
Employ demolitions to breach mines	4	4
Employ smoke pots	4	4
Feel heat and shock of blast wave	4	4
Follow route designated on map	4	4
Hear covered and concealed firing positions	4	4
Hear location of impact point of indirect fire based on sound	4	4
Identify extent of injury to soldier	4	4
Identify type of injury to a soldier	4	4
Move to a location on a map	4	4
Hear ORP locations that are easy to defend for a short time	4	5
Clear fields of fire	5	4
Perform chemical decontamination	5	4
Perform radiological decontamination	5	4

There are also a number of Activities that can be expected to transfer effectively and can be supported in the virtual environment with off-the-shelf or near term developmental technology, as shown in Table 11.

Table 11 Activities with High Transfer and Available Technology

Activity	Transfer	Difficulty
Engage aircraft with small arms	5	1
Inspect for correct "soldier's load"	4	1
Aim and fire crew served weapon	4	2
Aim and fire individual weapon	4	2
Aim and fire M203 GL	4	2
Aim and fire M60 MG	4	2
Call in preplanned fire requests	4	2
Determine direction distant aircraft is flying	4	2
Identify approach to LZ/DZ that is free of tall trees, etc.	4	2
Identify areas that mask supporting element fires	4	2
Identify distribution points for supplies	4	2
Identify firing positions in building	4	2
Identify firing positions in urban area	4	2
Identify orientation of main guns on vehicles	4	2
Identify orientation of soldier's weapon or fire	4	2
Identify overwatch position	4	2
Identify safe and danger area	4	2
Identify support position that will enable fire to be placed on enemy	4	2
Inspect boat landing	4	2
Orient map to field of view	4	2
Perceive relative position of weapon fire	4	2
Place weapons on safe	4	2
Position antitank mines	4	2
Position/sight weapons	4	2
Use password	4	2

Finally, there is a group of Activities that, while not promising in terms of expected transfer, are relatively straightforward to support in virtual environment practice and may be cost effective to support in the simulated world because of the contextual value they provide to higher transfer activities with which they aggregate to comprise Subtasks, Tasks, and Missions. These latter activities are shown in Table 12.

Table 12 Activities with Minimal Transfer and Available Technology

Activity	Transfer	Difficulty
Blow whistle for signal	2	1
Burn garbage and waste	2	2
Count ammunition	2	2
Count/inventory expendable supplies	2	2
Discern own movement direction	2	2
Hear orders	2	2
Hear own movement noise	2	2
Identify glow from cigarette	2	2
Identify ranks	2	2
Identify rear of armored vehicle	2	2
Identify side of tank	2	2
Identify slopes that must be climbed	2	2
Identify steep slopes	2	2
Mark vehicles	2	2
Operate radio or telephone	2	2
Read CEOIs	2	2
Read dosimeter scale	2	2
Read standard military symbols on a map	2	2
Read watch to tell time	2	2
Set frequency on radio	2	2
Smell smoke from cigarettes	2	2
Use binoculars	2	2
Use compass to determine azimuth readings	2	2
Use night vision devices	2	2

Of these, many occur relatively frequently as components of Subtasks. As an example, the Activity "hear orders" is a common component of many Subtasks (696 occurrences in 546 Subtasks). Of 546 total Subtasks in the four ARTEP/MTP's examined, only 17.2% of the Subtasks appear to be technically supportable in the near to mid term while also, in the judgment of the raters, offering effective training transfer in virtual environment practice.

While transfer ineffective activities are not practical targets for development and demonstration as isolated goals, many are relatively easy and inexpensive to support and may be defensible as a part of a hierarchical plan for aggregating

individual activities into increasingly sophisticated Task/Mission sequences as the more challenging activities can be demonstrated.

Activities that cannot be supported because of technological shortfalls need not be impediments to the developmental research schema suggested here. As an example, the activity "read a map" was judged to require more visual resolution than currently anticipated graphics systems could supply if imaged at real scale in a virtual environment presentation. However it may not be necessary to generate the map if the human observer is given the option to shift his attention to a real map - an alternative both less expensive and readily supportable now. Such work-arounds can be developed for many of the excluded Subtasks.

PLAN FOR HUMAN PERFORMANCE RESEARCH

Purpose of Research and Demonstrations

Earlier chapters have described the functions that need to be supported by virtual training environments for three specific training areas: (a) individual combat simulation, (b) mission planning and rehearsal, and (c) mission specific training. The earlier chapters also described the results of a survey of the state of the art in virtual environment technology for near-term availability, and the state of knowledge about the design features of virtual environments that impact their effectiveness in delivering training experiences. This chapter describes the specific tasks that are expected to be amenable to virtual environment-based training as the technology matures, and exposes the gaps in the knowledge base of virtual environment applications that must be filled to realize efficient and effective virtual environment training system designs.

This chapter describes a proposed plan for a program of human performance research and demonstrations leading to an understanding of when and how the technologies of virtual environments should be applied to train performance of tasks in the three training areas. As used herein, the word "demonstration" is used to mean the documentation of a research outcome. This plan should be considered a "strawman" document that will need to be updated to reflect a variety of factors, including: (a) advances in virtual environment technologies; (b) the results of ongoing research on human performance in virtual environments and the use of virtual environments for training; and (c) the availability of resources (personnel, facilities, and funding) to conduct the research. While the plan described may never be executed as described, it nevertheless provides a baseline which can be modified as required.

Prioritized Activities and Tasks

The ARTEP task analysis described earlier included a rating of the criticality of each task. However, if that task criticality rating were to be applied to the constituent activities, nearly every activity would be rated as "highly critical." For the purpose of determining the priority for investigating and demonstrating the activities and tasks, an alternative metric of the importance of the various activities was required. One such metric is the frequency that any one activity occurs within a task and across all tasks. To measure such frequencies of occurrence, all activities were first identified in all tasks from the ARTEP/MTP's. A matrix, illustrated in Table 13, was generated to enumerate all of the

activities associated with each task. The number of occurrences (frequency) of each activity in each task was calculated and entered as the cell entries.

Table 13 Example of Activities x Task Comparison

Transfer Effectiveness	Availability of Technology	Study/ Demonstration Priority	Activity	Task 1 7-3/4-1011 Assault	Task 2 7-3/4-1007 Overwatch	Task 3 7-3/4-1008 Disengage	...	Task 67 7-3/4-9012 React to Nuclear Attack
5	2	1	Engage aircraft with small arms					
5	3	2	Discriminate between friendly and enemy aircraft					
5	4	3	Clear fields of fire					
5	4	4	Perform chemical decontamination					
5	4	5	Perform radiological decontamination					
4	1	6	Call in preplanned fire requests					
4	1	7	Inspect for correct "soldier's load"					
			...					
1	5	252	Search, gag, and tag POWs					

The activities (rows) were prioritized by sorting them in the following order:

1 Availability of VR technology, with immediately available technology shown first;
2 Total occurrences of activity within all tasks, with the most frequent occurrences shown first; and
3 Transfer effectiveness, with high transfer effectiveness shown first.

To prioritize the tasks, the columns were sorted in the following order:

1 Number of near-term activities occurring in the task, with the most frequent occurrences shown first;
2 Number of mid-term activities occurring in the task, with the most frequent occurrences shown first; and
3 Number of far-term activities occurring in the task, with the most frequent occurrences shown first.

The prioritized matrix of activities and tasks is at Appendix E: Activities and Tasks for Individual Combatants.

Activities Supported by Near-Term Technology

Of the 86 activities that can be supported in the near-term, 37 activities each occur in more than five tasks and were therefore identified as being sufficiently important to warrant study and demonstration in a virtual environment. Additionally, seven activities that occur infrequently (in less than five tasks) were included in the list of activities to be demonstrated in the near-term. Several of these additional activities were included to provide a complete set of activities involving a single type of equipment (e.g., the activity "Place LAW in operation" complements the more frequent activity "Aim and fire LAW). Several other activities (e.g., "Hear own movement noise") were included since these activities require technical support (e.g., directional acoustic display) that ought to be demonstrated to fully explore the technology of virtual environments. Table 14 shows these activities, with the subjective estimates of the transfer effectiveness of training of these activities in virtual practice environments.

Table 14 Prioritized Activities Supported in the Near-Term

Demonstration Priority	Activity Priority	Activity	# Occurrences of Activity	# Tasks with Activity	Transfer Effectiveness	Availability of Technology
1	1	Give verbal orders	490	67	3	1
2	2	Use password	24	12	4	1
3	3	Call in preplanned fire requests	11	11	4	1
4	4	Blow whistle for signal	13	8	2	1
5	5	Hear orders	442	66	2	2
6	6	Operate radio or telephone	89	41	2	2
7	7	Identify safe and danger area	68	32	4	2
8	8	Perceive relative position of other units	63	29	3	2
9	9	Visually search for enemy	50	27	3	2
10	10	Move in accordance with directions	50	22	4	2
11	11	Give hand and arm signals	58	21	3	2
12	12	Aim and fire individual weapon	45	20	4	2
13	13	Maintain position relative to other personnel	37	20	3	2
14	14	Aim and fire crew served weapon	43	19	4	2
15	15	Identify hand and arm signals	47	17	3	2
16	16	Aim and fire M60 MG	43	17	4	2
17	17	Aim and fire M203 GL	41	17	4	2
18	18	Identify support position that will enable fire to be placed on enemy	40	17	4	2
19	19	Read standard military symbols on a map	32	17	2	2
20	20	Perceive relative position of weapon fire	26	17	4	2
21	21	Identify areas that mask supporting element fires	26	15	4	2
22	22	Identify overwatch position	27	12	4	2
23	23	Place crew served weapons in operation	12	11	4	2
24	24	Identify light-reflected from shiny objects	12	10	2	2
25	25	Change rate of fire	17	9	4	2
26	26	Identify glow from cigarette	9	9	2	2
27	27	Fire flare to signal	13	8	3	2
28	28	Identify dead space	12	8	3	2
29	29	Read CEOIs	8	8	2	2
30	30	Identify obstacles	12	7	4	2
31	31	Arm hand grenade	11	7	4	2
32	32	Identify orientation of soldier's weapon or fire	7	7	4	2
33	33	Identify flashes from enemy weapons	7	7	3	2
34	34	Aim and fire LAW	12	6	4	2
35	35	Discern location within an area	10	6	3	2
36	36	Read dosimeter scale	10	6	2	2
37	37	Set frequency on radio	10	6	2	2

Table 14 Prioritized Activities Supported in the Near-Term (cont'd)

Demonstration Priority	Activity Priority	Activity	# Occurrences of Activity	# Tasks with Activity	Transfer Effectiveness	Availability of Technology
38	38	Aim, fire, and track DRAGON	10	5	4	4
39	39	Hear own movement noise	8	5	2	2
40	44	Identify firing positions in building	7	4	4	2
41	45	Identify orientation of main guns on vehicles	4	4	4	2
42	46	Discern direction enemy is moving	4	4	3	2
43	47	Place LAW in operation	4	4	3	2
44	48	Prepare DRAGON sight	4	4	3	2

Activities Supported by Mid-Term Technology

Of the 124 activities that can be technically supported in the mid-term, 44 occurred in more than five tasks and were identified as being sufficiently important for further study and demonstration in a virtual environment. Additionally, four tasks that occur infrequently (in less than five tasks) were included in the list of activities to be demonstrated in the mid-term. These activities (e.g., "Identify squad voices") were included since these activities require technical support (e.g., directional acoustic display) that ought to be demonstrated to fully explore the technology of virtual environments. Table 15 shows the activities with the subjective estimates of the transfer effectiveness of these activities in virtual environments.

Table 15 Prioritized Activities Supported in the Mid-Term

Demonstration Priority	Activity Priority	Activity	# Occurrences of Activity	# Tasks with Activity	Transfer Effectiveness	Availability of Technology
45	87	Move upright, tactically	79	36	2	3
46	88	Identify actual squad members	70	35	2	3
47	89	Identify covered and concealed route	77	33	4	3
48	90	Move upright, reconnoiter	52	22	2	3
49	91	Inspect Equipment	42	22	4	3
50	92	Identify assigned sectors	49	21	3	3
51	93	Estimate distance from self to a distant point	35	19	3	3
52	94	Read charts and diagrams	34	19	3	3
53	95	Distribute supplies and equipment	38	18	3	3
54	96	Identify restricted fire lines, check points, etc.	26	17	3	3
55	97	Move by rush	32	16	2	3
56	98	Identify activity of personnel	25	16	3	3
57	99	Identify actual chain of command	21	16	2	3
58	100	Identify enemy soldiers	29	15	4	3
59	101	Record observation notes	28	13	2	3
60	102	Administer first aid	19	13	3	3
61	103	Move with stealth	26	11	2	3
62	104	Read written order	25	11	2	3
63	105	Carry protective mask	19	11	2	3
[illegible]	106	Identify enemy voices	11	11	3	3
65	107	Operate chemical-alarm	26	10	4	3
66	108	Position/sight weapons	16	9	4	3
67	109	Move upright rapidly, tactically	16	9	2	3
68	110	Count members of the squad	12	9	2	3
69	111	Identify civilians	11	9	4	3
70	112	Check radiac instruments	25	8	2	3
71	113	Prepare demolitions	14	8	4	3
72	114	Follow route designated on map	11	8	4	3
73	115	Throw smoke grenade	10	8	2	3
74	116	Se[illegible] u[illegible] early warning (trip wire) devices	9	8	4	3
75	117	Attach telephone to commo wire	9	7	2	3
76	118	Dismount vehicle	9	7	2	3
77	119	Set up and employ Claymore mines	9	7	2	3
78	120	Discern map coordinates for indirect fire	7	6	4	3
79	121	Identify damage to equipment	6	6	3	3
80	122	Throw grenade	6	6	2	3
81	124	Identify squad voices	8	5	3	3
82	132	Determine own location on map with respect to control measures	5	4	4	3
83	145	Clear obstacles	3	3	2	3
84	146	Move by low crawl	3	3	2	3

Activities Supported by Far-Term Technology

Forty-two activities were found to require far-term technology for performance in virtual environments. Thirteen activities were identified for further study and demonstration in a virtual environment. Additionally, two activities that occur infrequently (in less than five tasks) were included in the list of activities to be demonstrated in the far-term. These activities ("Hear covered and concealed firing locations") were included since these activities require technical support (e.g., directional acoustic display) that ought to be demonstrated to fully explore the technology of virtual environments. Table 16 shows the activities that can be supported in the far-term, and that occur in more than five of the 67 tasks, plus the two less-frequent activities that were also identified for demonstration in the mid-term.

Table 16 Prioritized Activities Supported in the Far-Term

Demonstration Priority	Activity Priority	Activity	# Occurrences of Activity	# Tasks with Activity	Transfer Effectiveness	Availability of Technology
85	211	Read a map	52	24	3	4
86	212	Identify camouflaged individual	17	11	3	4
87	213	Remove signs of presence	16	11	2	4
88	214	Move to a location on a map	12	8	4	4
89	215	Establish cache	10	8	3	4
90	216	Camouflage fighting position	9	8	2	4
91	217	Waterproof water-sensitive items	9	8	2	4
92	218	Activate demolitions	10	7	3	4
93	219	Camouflage trail after passing	7	7	2	4
94	220	Perform chemical decontamination	21	6	5	4
95	221	Construct fighting position with overhead cover	11	6	3	4
96	222	Dig hasty fighting position	8	6	3	4
97	223	Remove debris from LZ	7	6	2	4
98	224	Hear covered and concealed firing positions	5	5	4	4
99	225	Clear an objective	6	4	3	4

Research and Demonstration Plan

Research and Demonstration Approach

The research and demonstration program could be conducted as a series of ever-more complex events that build upon the capabilities demonstrated in the previous developments. The objectives of the research and demonstration program would be to:

Conduct research in a single testbed facility that can be

rapidly integrated from available technology to produce immediate payoff.

Provide both general domain knowledge and specific data facilitating rapid and effective exploitation of virtual environments.

Utilize available technology to address research issues in a sequence that provides high payoff in the short term.

Drive the development of, test, and evaluate new virtual interface technologies.

Incorporate and exploit new technologies as they become available to continuously redirect the research focus to those areas of highest value.

Sequence the experiments and demonstrations so that lessons learned in early experiments reduce the cost and increase the probability of success in those that follow.

Utilize the talent of the testbed staff efficiently by changing the personnel mix to match the domain expertise demands of the issues under investigation.

Develop optimal design strategies for virtual environments and systems that create and utilize them.

Identify appropriate measures of performance for individual and collective training in virtual environments and examine means to collect them.

Explore training strategies appropriate for individual and collective virtual environment training systems.

Develop guidelines for verification, validation, and accreditation of virtual environments for practice of individual and collective combatant skills.

Serve as technical exemplar for potential users of virtual environment training technology to expand the range of options available for consideration in conceptualizing new training solutions.

Respond to changing user needs as driven by combat developments, evolving tactics and doctrine, and changing soldier characteristics.

The initial experiments and demonstrations would focus on individual combatant activities and tasks that could be accomplished in the near-term with technology that is currently available (with modification as necessary). In so doing, these

initial efforts could illustrate the technologies that currently support individual combat tasks, and could highlight areas of deficiency, both in terms of the technology that must be developed, and tasks that are not yet supportable in virtual environments. The focus of subsequent experiments and demonstrations could change to an orderly process of filling in the gaps in knowledge and technologies and expanding the range of individual ARTEP tasks that can be supported in virtual environments. This latter objective could be accomplished by demonstrating the performance of the activities in the mid- and far-term, which can then be combined with the activities demonstrated in the initial experiments to form complete ARTEP tasks.

An additional focus of the subsequent experiments and demonstrations could be to explore and evaluate specific technical approaches (e.g., a high-resolution head-mounted binocular visual display, a hand-mounted tactile display, etc.) as applied to an integrated ICS system. Such an integrated system could then be used to evaluate the interaction of individual technologies.

Research Issues

The research issues to be considered for investigation in the ICS Testbed derive from several converging sources. On the one hand, the Department of Defense, and the Army in particular, has committed itself to broad applications of virtual environments, not only for training, but also for operational rehearsal, materiel acquisition, and program analysis and evaluation. On the other hand, the virtual battlefields being created to support these functions, including both the current Combined Arms Tactical Training System and the near-term follow-on Close Combat Tactical Trainer (CCTT) do not realistically accommodate dismounted combatants. Finally, the current effort has identified a number of tactically meaningful activities and tasks that have been judged to be supportable by the technology of virtual environments in the near-term, mid-term, and far-term. Several global research issues evolve naturally from these various sources.

Human Performance Supported by Virtual Environments

A primary focus of the research and demonstrations proposed for the ICS Testbed is an identification of the activities that could be trained in virtual environments. A first step is to determine the cueing and response characteristics of the virtual environments required to adequately support performance of the individual combatant activities. Furthermore, to be useful in characterizing virtual environments, it is desirable to identify the functional relationships between the levels of cueing and response characteristics of the virtual environment and the

demonstrated performance of the various activities. The first research question thus becomes "What is the relationship between performance level of the activities demonstrated and the various performance levels of cueing and response technology in the virtual environment?" This first research question should be the focus of the initial experiments and demonstrations described in this research plan. It is intended to develop an understanding of the optimal testbed configuration for subsequent investigations.

Activities That Can Be Trained in Virtual Environments

A second research issue to be addressed in the ICS Testbed is the question of what individual combatant activities can be trained in virtual environments. The current effort has identified tactically meaningful activities that have been judged to be supportable by the technology. A research question to be answered empirically through investigations in the ICS Testbed is "Does virtual environment technology support training the activities performed by individual dismounted combatants?"

Inherent in the basic question of what activities and tasks can be trained in virtual environments is the recognition that the characteristics of a simulation system that support training are not necessarily the same characteristics required to facilitate high performance, and vice versa. One distinction between performance and training concerns the feedback of the knowledge of results. In the case of performance, knowledge of results - feedback - guides the ongoing response, while in the case of training, feedback enables the performer to improve subsequent responses. These can be described as performance feedback and learning feedback, respectively. Holding (1965) suggests that knowledge of results can be classified along several dichotomous dimensions, including (a) intrinsic vs. artificial, (b) concurrent vs. terminal, (c) immediate vs. delayed, (d) non-verbal vs. verbal, and (e) separate vs. accumulated. Any task situation can be characterized by some combination of all five dimensions of the knowledge of results, and the full set of combinations can be illustrated as a tree structure. According to this categorization, knowledge of results that is artificial, terminal, delayed, verbal, and accumulated would be most supportive of learning, while knowledge of results that is intrinsic, concurrent, immediate, non-verbal, and separate would be most supportive of performance.

This classification of knowledge of results suggests that virtual environments may be more appropriate for enhancing performance than for enhancing learning, since the type of feedback of such "immersive" environments appears, on the surface, to be largely intrinsic, concurrent, immediate, non-verbal, and separate. The research question thus becomes "Does practice in a virtual environment lead to improved performance of

the identified activities and tasks in the real-world environment (i.e., enhanced learning), or does the practice merely promote performance in the virtual environment itself with little or no improvement in the real-world environment (i.e., enhanced performance)?" Obviously, this question is one demanding of experimental investigation.

A related research question focuses on the appropriateness of using virtual environment technologies to train the activities and tasks - "Is a virtual environment an effective means for training the identified activities and tasks?" This latter question is distinct from the more basic question of whether virtual environments can be used to train the tasks. Rather, it is a question of the training effectiveness of virtual environments compared to other methods of training.

With regard to simulators and simulated environments, the measurement of the effectiveness of training implies evaluation of transfer of training - that is, assessment of performance in the criterion environment following training in the simulated environment. Any question of training effectiveness naturally leads to evaluations of transfer of training, since effectiveness is typically described in terms of the increased task performance in the actual or real-world setting. Therefore, it is appropriate to consider the obstacles to be overcome in transfer of training experiments.

Transfer experiments are difficult to perform because the main effect variances are typically masked by a substantial residual variance attributable to inter-subject differences in aptitude and prior experience, and intra-subject variability in performance within trials due to any number of physical or psychological variables that are uncontrolled between sessions. There are a number of experimental strategies for dealing with these problems that have some ameliorating effect. Careful matching of test subjects to balance extraneous factors among treatment groups minimizes the problem if these factors can be identified and measured a priori. Even where treatment group balancing is impossible, estimates of significant covariates of dependent variable measures can be used to adjust experimental data to achieve some measure of balance post hoc.

A second concern in transfer experiments are the issues of skill acquisition and extinction rates. When dealing with certain classes of skills, acquisition may require a significant number of practice trials to observe terminal levels of performance. Pre-test trials must be used to estimate the rate of acquisition, so that transfer effectiveness measures reflect mature learning, and not initial gains subject to later significant improvement. Other types of skills may be subject to rapid extinction. The virtual practice environment may find its greatest application in relation to these skills as a sustainment

training environment rather than as an initial acquisition aid. Experimentation with this class of activities should be oriented to estimating the retention and extinction characteristics of the learned behaviors and the transfer effectiveness measures made with respect to sustainment.

Closely related to the question of the training effectiveness of virtual environments is the question of the appropriate strategy(ies) for training particular activities and tasks in virtual environments. Indeed, training effectiveness is a direct function of the strategies that are employed. For example, empirical research may demonstrate that virtual environments are inappropriate for training isolated activities or tasks, while demonstrating that these same environments are well-suited for training activities and tasks that are grouped into tactically meaningful clusters, or that comprise a specific mission. An appropriate series of experiments to be conducted in the ICS Testbed is an examination of alternative training strategies.

Training and Immersion in Virtual Environments

One family of issues to be addressed concerns the degree of immersion that the participant experiences in a virtual environment and the impact of that immersion on training. This issue need not be restricted to dismounted combatants; however, the ICS Testbed will provide an ideal research environment for investigating the issue.

A distinction that has been made among various forms of virtual environments concerns the degree of involvement or "immersion" that is experienced by the participants. At one end of the spectrum, called "immersive" virtual environments, participants perceive themselves as being within the simulated world. Head mounted displays and cybergloves provide such an experience. At the other end of this spectrum, sometimes called "third party" virtual environments, participants view themselves as being outside of the simulated world, but manipulating or controlling objects or icons that are within it. For example, a teenager standing in front of a console-type video game may be fully mindful that he is standing in a video arcade, but he sees himself as the proximal controller of the "creature" on the video screen. Somewhere between are "portal" virtual environments, in which the participants view the virtual space through a window. A race car game that shows the driver's windshield view of the race gives a viewer the vicarious impression of participating in an auto race, yet isolated from the virtual environment by the intervening barrier of the car.

Virtual environments are often described in terms of the degree of "involvement" of the participants in the situation being simulated. The sense of being immersed in the situation

being simulated is often called "presence." Indeed, at least in the popular literature of virtual reality, a successful virtual environment is often defined as one that creates such a sense of "presence." If such a sense of presence is central to the definition of virtual environments themselves, several research issues become candidates for experimental examination, such as:

What is the sense of presence (i.e., how is it measured)?

What is the relationship between the reported sense of presence and the training effectiveness of the virtual environment?

How is the sense of presence acquired or created?

What elements of the virtual environment increase (or decrease) the sense of presence?"

It would appear on the surface that one characteristic of virtual environments that may contribute to the sense of presence, or the sense of immersion, is the verisimilitude between the simulated world and it's real-world counterpart. In the world of simulators, verisimilitude is often measured in terms of "degree of fidelity." However, the concept of simulator fidelity typically refers to the degree of physical correspondence between the simulator and the real-world (e.g., the look and feel of the interior, the similarity between the display visual scene and the real-world scene, etc.). As used herein, verisimilitude includes not only any dimension of physical correspondence, but also functional and behavioral correspondence. However one chooses to characterize the correspondence between the virtual environment and its real-world (or fantasy) counterpart, it quickly becomes evident that such correspondence is multi-dimensional, and any measurements of the sense of "presence" or "immersion" must also be multi-dimensional.

Secondary Effects of Virtual Environments

A fourth research issue to be considered focuses on secondary effects that may occur while performing in a virtual environment. The research question becomes "Do detrimental side effects occur with performance of the activities in a virtual environment? If so, what are they, and how can they be ameliorated?"

One concern that has be raised with virtual environments is the phenomenon of "simulator sickness." For example, some participants in flight simulators experience disorientation or even nausea during or some time after a simulator session. The phenomenon appears to be associated primarily with visual effects (e.g., rapid pans of the scene) that are not correlated with motion effects in the same manner as would be experienced in the

real-world (i.e., in an actual aircraft). In the present case of dismounted combatants moving at walking speed and moving the head in a normal manner, does a similar disorienting or nausea-inducing effect occur?

Other side effects of concern for dismounted combatants focus on artifacts that may be induced by the technology required to provide the virtual environment. The current technology for creating virtual environments for individuals typically requires some "umbilical" connections (e.g., wires stretching from the person to some attachment point in the real space) that can impede free movement. In the case of head-mounted displays, an un-natural mass on the head can also impede movement or become excessively uncomfortable. Other artifacts created by the technology include delays between movement of body parts (e.g., head movement) and corresponding changes in the display of the virtual world. Such control-display lags can be quite disorienting, to the point of disrupting performance of on-going activities, and even inducing discomfort.

The focus of this fourth research issue will be to record instances of such secondary effects, and to identify apparent contributors to the effects. This issue will be included with the experiments that consider the previous issues, and any secondary effects that are noted during those experiments will be examined within the context of those other research activities.

Research Strategy

As described earlier, the activities that constitute the ARTEP tasks cluster into three groups that can be supported by virtual environment technology in the near-term, mid-term, and far-term. The research and demonstrations to be conducted in the ICS Testbed should capitalize on this clustering by examining the constituent activities in a sequential manner. The experiments and demonstrations should start with experimental examinations of the near-term activities. The mid-term activities should then be added in a subsequent set of experiments and demonstrations to illustrate the performance of more complex clusters of activities. Finally, the far-term activities should be added, making it possible to study and demonstrate the performance of ARTEP tasks in a virtual environment.

This research plan describes in detail the experiments to be conducted with near-term activities. The objectives and general approaches of the mid-term and far-term experiments are also described, however, the details of these latter experiments will depend upon the experimental results and suggestions from the earlier research activities in the sequence.

Near-Term Research and Demonstrations

Research Experiments

The research plan describes a sequential series of experiments and demonstrations to be conducted with the near-term activities to address the various research issues. The initial experiments would focus on the near-term activities that can be performed in the virtual environment, the interim experiments would focus on the near-term activities that can be trained in virtual environments, and the last experiments in the sequence would focus on the characteristics of virtual environments that contribute to training and any secondary effects of performing the near-term activities in virtual environments.

Identification of Activity Performance in Virtual Environments. Two initial experiments and demonstrations focus on the first research issue - "What performance level of the activities can be demonstrated for the various levels of each cueing and response technology in the virtual environment?" The first initial experiment (experiment 1.1) would be conducted to identify the near-term activities that could be performed in the ICS Testbed with the currently-available (i.e., near-term) technical capabilities. This first initial experiment would serve two primary purposes: (1) to indicate those near-term ARTEP activities that can be performed in a virtual environment, given the currently-available technology; and (2) to estimate the variance of the subjects' performance in the virtual environment. The latter would be used to determine sample sizes in subsequent research activities.

A second initial experiment (experiment 1.2) would be undertaken to identify functional relationships between various levels of technology and the performance of the activities in the virtual environment. This experiment is not intended to examine the entire domain of possible variations exhaustively in display, acoustic, tactile, force feedback, and olfactory display technologies or the full range of response technologies. Rather, it is intended to provide an indication of the sensitivity of activity performance to large changes in those aspects of virtual environment technology that are commonly expected to affect performance. Two levels of each of several major technology attributes would be varied to identify some of the primary contributors to variance in performance in virtual environments.

Both of these initial experiments would be conducted with the three vignettes that are described herein. These experiments would provide a first opportunity to verify that the vignettes are useful clusters of activities that can provide a convenient mechanism for creating scenarios that are militarily meaningful, are self-contained with a defined beginning and end, and have an overall goal.

The objective of the initial experiments is to identify activities that can be demonstrated in the virtual environment. Thus, the subjects must be able to perform the activities prior to attempting to perform in the virtual environment. Infantry enlisted personnel who have completed the Advanced Individual Training (AIT) course are qualified to perform all of the activities, and should be used as subjects for these initial experiments.

Evaluation of Virtual Environments for Training Activities. Two interim experiments and demonstrations would address the second research issue - "Does virtual environment technology support training the activities performed by individual dismounted combatants?" Whereas the initial experiments would focus on identifying the activities that can be performed in the virtual environment, the interim experiment would focus on identifying those near-term tasks that could be trained in the virtual environment. The interim experiments would include only those near-term activities from Table 14 that were shown in the initial experiments to be performed in the virtual environment.

Both interim experiments would use a transfer of training paradigm to assess the amount and effectiveness of training provided by performing the near-term activities in the virtual environment. In the first interim experiment (experiment 2.1), three groups of similar subjects would be used to identify those near-term activities that can be trained in the virtual environment. The first group would be instructed to perform the activities in the ICS Testbed, and would then perform the activities in a real-world terrain area that is similar to the virtual terrain area. The second group would only perform the activities in the real-world terrain area, while the third group would perform unrelated activities in the ICS Testbed, and would then perform the activities in the real-world terrain area. A comparison of the real-world activity performance between the first and second groups would give a measure of the amount of training on each activity, while a comparison of the real-world activity performance of the first and third groups would give a measure of any effects of simply performing in a virtual world.

A second interim experiment (experiment 2.2) would examine the functional relationships among various levels of technology and the effectiveness of training the activities in the virtual environment. This second interim experiment would include only those mid-term activities that were shown to be trainable in a virtual environment from the first interim experiment.

This second experiment would also include only two groups of subjects: one group would perform activities in the virtual environment and then in the real-world terrain area, while the second would perform the activities only in the real-world terrain area. Only those technology attributes that were shown

in the second initial experiment to affect performance in the virtual environment would be used in this second interim experiment of training in the virtual environment.

The objective of the interim experiments is to identify activities that can be trained in the virtual environment. Thus, the subjects must be untrained in the activities prior to attempting to perform in the virtual environment. Enlisted personnel who have completed the Basic course, but who have not yet completed the Advanced Individual Training (AIT) course are untrained in the activities, and should be used as subjects for these initial experiments.

Evaluation of Immersion in the Virtual Environment. A final experiment of the near-term activities (experiment 3.1) would examine any effects on performance and training of the "immersion" characteristic of virtual environments. The focus of this experiment would be to identify any differences in training effectiveness between two variations of virtual environments, which vary in degree of immersion in the simulations. In this experiment, two groups of subjects would be used. The first group - the "immersion" group - would be identical to the first group of experiment 2.2. The subjects would be instructed to perform in the virtual environment those near-term activities that do not require any props (e.g., Identify safe and danger area, Visually search for the enemy), and they would then perform those same activities in the real-world terrain area. During this evaluation, tasks that require the use of tools or weapons would not be performed since props can only be supported in the "immersion" environment, therefore the task could not be adequately supported in the "portal" environment.

The second group of subjects - the "manipulation" group - would perform the activities in a variation of the virtual environment. Rather than performing the tasks directly in the ICS Testbed, the subjects would operate from a workstation similar to the observer's workstation. In this case, each subject would use joysticks to control the actions of a "stick figure" icon that represents a dismounted combatant. The participant could see 3-D (non-stereoscopic) views of the terrain from any point-of-view outside of the icon (e.g., slightly behind and above the icon, or from directly above as in a map-like view) or directly from the icon's own point-of-view. However, in both cases, the views of the terrain would be shown on the workstation display, not on a head-mounted display.

As in the case of the interim experiments, the final experiment would also use a transfer of training paradigm, in which the subjects from both groups would subsequently perform the activities in the real-world terrain area.

All experiments of the near-term activities would also examine any side effects of virtual environment technologies. Thus, some of the qualitative measures of performance (particularly post-session questionnaires) would seek to identify sources of discomfort, disorientation, nausea, interference, or encumbrances.

The experiments to be conducted with the near-term activities are summarized in Table 17.

Table 17 Summary of Near-Term Experiments

Experiment Number	Experiment Focus	Independent Variables
1.1	Activities that Can be Performed in VE	44 Near-Term Activities
1.2	VE Attributes Contributing to Performance	Near-Term Activities that can be Performed
		Display Type Display Resolution # Scene Polygons Terrain Resolution Auditory Localization Control Device Type
2.1	Activities than Can be Trained in VE	Near-Term Activities that can be Performed
2.2	VE Attributes Contributing to Training	Near-Term Activities that can be Performed
		To be Determined from: • Display Type • Display Resolution • # Scene Polygons • Terrain Resolution • Auditory Localization • etc.
3.1	Immersion in the Virtual Environment	Near-Term Activities that can be Performed
		Immersion vs Manipulation

Research Scenarios

From an experimental design standpoint, it would be impractical to examine each activity individually, but it is possible to group the activities into a manageable number for investigation.

The near-term experiments and demonstrations would be conducted with a series of vignettes consisting of groups of increasingly demanding activities from the list of 44 activities

identified for study in the near-term (shown previously in Table 14). The vignettes are designed to cluster activities with similar technology demands and with similar performance characteristics, facilitating experimental manipulation and presentation of technical capabilities in the ICS Testbed.

The sequence of vignettes would also build upon the ever-increasing technical capabilities of the ICS Testbed to support performance of the required activities. To the extent possible, the vignettes are also designed to be a meaningful sequence of activities, with a defined beginning, end, and overall goal.

Vignette 1 - Visually Survey Terrain Areas. In this vignette, the subjects would receive their orders, visually survey an area of the virtual terrain, and verbally report the results of their survey. The constituent activities of this vignette (taken from Table 14) are shown in Table 18.

As can be seen from the list of constituent activities, the focus of this vignette is on visual identification by dismounted combatants of portions of the virtual world and actions by other military entities on the terrain (e.g., enemy fire, etc.). Not all of the elements to be identified would typically be within visual range of a single location on the virtual terrain. Thus some mechanism must be provided to move the dismounted combatants from one location to another. This could be done by: (a) allowing the participants to move their virtual representations (i.e., "icons") through the virtual environment with some device (e.g., a joystick); or (b) moving the combatants' icons automatically (e.g., "beaming" them from location to location or moving them across the terrain at the typical speed of a dismounted soldier). The choice is left to the experimenters.

Table 18 Constituent Activities of Vignette 1

Demonstration Priority	Activity
5	Hear orders
7	Identify safe and danger area
9	Visually search for enemy
18	Identify support position that will enable fire to be placed on enemy
21	Identify areas that mask supporting element fires
22	Identify overwatch position
24	Identify light-reflected from shiny objects
26	Identify glow from cigarette
28	Identify dead space
30	Identify obstacles
32	Identify orientation of soldier's weapon or fire
33	Identify flashes from enemy weapons
35	Discern location within an area
40	Identify firing positions in building
41	Identify orientation of main guns of vehicles
42	Discern direction enemy is moving

The participants would be instructed that the objective is to identify and verbally report on areas and locations of military significance on the terrain (e.g., suitable overwatch positions) and actions by enemy soldiers or vehicles. After the participant has entered the virtual world (e.g., is in the Individual Combat Simulator (ICS), described in the next chapter) he would be given verbal instructions via the ICS audio system to search for and identify (i.e., describe verbally) the items listed in Table 18. To maintain the illusion of a military operation, these instructions would be given in the form of a Fragmentary Order (FRAGO), and the participant would be requested to report the identification of items in the form of Spot Reports, as they would be given verbally via a radio (although operation of a radio would not be required).

Vignette 2 - Working with Other Dismounted Combatants. In this vignette, the subjects would receive their orders, give orders to other squad members, observe and direct the actions of squad members, and coordinate actions with other military units. This vignette would focus on multiple participants operating simultaneously in the virtual environment. The constituent activities of this vignette (taken from Table 14) are shown in Table 1..

Table 19 Constituent Activities of Vignette 2

Demonstration Priority	Activity
1	Give verbal orders
2	Use password
3	Call in preplanned fire requests
4	Blow whistle for signal
5	Hear orders
8	Perceive relative position of other units
10	Move in accordance with directions
11	Give hand and arm signals
13	Maintain position relative to other personnel
15	Identify hand and arm signals
19	Read standard military symbols on a map
27	Fire flare to signal
29	Read CEOIs
32	Identify orientation of soldier's weapon or fire

As shown Table 19, the focus of this vignette is on performing activities in the virtual environment in coordination with other participants who are also in the virtual environment. This vignette also includes reading selected portions of printed materials (e.g., military symbols on a map, CEOI). In this vignette, the participants must visually observe the actions of the other participants, and communicate with those other participants by giving and receiving verbal orders and reports, and visual signals (e.g., arm and hand signals). Activities from Vignette 1 can also be included in this vignette as necessary to provide a consistent and logically complete scenario. As in the first vignette, some mechanism must be provided to move the dismounted combatants from one location to another.

The participants would be instructed that the objective is to operate as a team with other participants in the virtual battlefield. One of the two participants would be designated as the team leader, while the second participant would be designated as a team member. The team leader would be instructed to command the squad by issuing orders and receiving reports. The team member would be instructed to follow the orders of the team leader, and to report as requested. After the participants have entered the ICS, they would be given verbal instructions via the ICS audio system to move across the terrain and to maintain tactical spacing among squad members. The instructions would be given to the Team Leader in the form of a FRAGO, who would then issue a FRAGO to the team member. Both participants would be requested to report the identification of items in the form of Spot Reports, as they would be given verbally via a radio

(although operation of a radio would not be required). The Team Leader would also be ordered to call for fires from the Fire Support Element, and to issue a Spot Report back to the Fire Support Element.

Vignette 3 - Operating Individual and Crew-Served Weapons and Equipment. In this vignette, the subjects would receive their orders, give orders to other squad members, operate individual weapons and equipment, and operate crew-served weapons. As in Vignette 2, this vignette would also focus on multiple participants operating simultaneously in the virtual environment. The constituent activities of this vignette (taken from Table 14) are shown in Table 20.

Table 20 Constituent Activities of Vignette 3

Demonstration Priority	Activity
1	Give verbal orders
5	Hear orders
6	Operate radio or telephone
12	Aim and fire individual weapon
14	Aim and fire crew served weapon
16	Aim and fire M60 MG
17	Aim and fire M203 GL
20	Perceive relative position of weapon fire
21	Identify areas that mask supporting element fires
23	Place crew served weapons in operation
25	Change rate of fire
31	Arm hand grenade
34	Aim and fire LAW
36	Read dosimeter scale
37	Set frequency on radio
43	Place LAW in operation
44	Prepare DRAGON sight

The focus of this vignette is on performing activities with equipment and weapons in the virtual environment, both individually and in coordination with other participants who are also in the virtual environment. In this vignette, the participants must set up and operate various types of equipment and weapons in the virtual environment, and observe the effects of operating the equipment and weapons, or observe the effects of other people operating equipment and weapons. Activities from Vignettes 1 and 2 can also be included in this vignette as necessary to provide a consistent and logically complete scenario. As in the first two vignettes, some mechanism must be

provided to move the dismounted combatants from one location to another. Three dimensional instrumented props would be provided to represent the weapons and equipment needed.

The participants would be instructed that the objective is to operate infantry-type weapons and equipment in the virtual battlefield. One of the two participants would be designated as the team leader (i.e., the commander), while the second participant would be designated as a team member. The team leader would be instructed to command the squad by issuing orders and receiving reports. The team member would be instructed to follow the orders of the team leader, and to report as requested. After the participants have entered the ICS, they would be given verbal instructions via the ICS audio system to set up and operate the various weapons listed in Table 20. The instructions would be given to the Team Leader in the form of a FRAGO, who would then issue a FRAGO to the team member.

Research Design

Independent Variables. The independent variables in the experiments to be conducted in the ICS Testbed include: (a) the activities that have been identified in the current program; and (b) the technologies that can be used to create a virtual environment for an individual (as opposed to those technologies used to create a virtual environment for crews operating in a simulated vehicle). The full range of independent variables that could be considered include all items in section 4 (i.e., Technology Considerations) of Appendix A: Virtual Environment Taxonomy. However, this becomes an intractable number of variables for experimentation. Thus, we would restrict the number of variables to those shown in Table 21, which can be varied given the technology approaches available at the Initial Operational Capability (IOC) of the ICS Testbed.

Table 21 Independent Variables of Near-Term Studies

Variable Number	Variable
	Cueing Mechanisms
	Visual Display
1	Type
	Stereoscopic
	Non-Stereoscopic
2	Scene resolution (# of resolution elements)
	Medium (1280 h x 1024 v)
	Low (640 h x 480 v)
	Terrain Database
3	Number of Scene Polygons
	~5000
	~1000
4	Resolution
	10 m vertical x 100 m horizontal
	2 m vertical x 50 m horizontal
	Auditory Display
5	Localization vs No-localization
	Response Mechanisms
6	Control Devices
	Joysticks
	Instrumented Objects
7	**Activities (near-term activities that can be performed)**

Measures of Performance/Effectiveness of Individual Combatants in Virtual Environments. The objective of the current program is to demonstrate and evaluate the virtual environment technologies that are required to support the ARTEP activities and tasks performed by individual combatants. According to accepted behavioral analysis and measurement methods, evaluators should select measures that are (a) highly related to the output or product of the performance being measured, (b) objective, (c) quantitative, (d) unobtrusive, (e) easy to collect, (f) require no specialized data collection techniques, (g) are not excessively molecular and therefore require no specialized instrumentation, and (h) cost as little as possible (Meister, 1985).

However, as Meister points out, few measures satisfy all these criteria, and while they are easy to state, they are quite difficult to apply in real world evaluation. Generally, measures of performance may either describe the terminal performance (the output of the operator action), or intermediate performance (an

operator behavior leading up to an output). In the current research, terminal measures are presumed to be more valuable than intermediate ones, because the evaluator is interested in outputs, although intermediate measures may be useful for diagnosing certain types of performance difficulties. Another difficulty here is that many of the tasks being measured are cognitive, and these significant performance dimensions are linked to other behaviors not immediately observable. Indeed, upon review of the activities described in Vignettes 1 and 2, it becomes obvious that many measures of performance would only be observable as secondary measures through their dependency relationships to other tasks (i.e., "hear an order" is not truly directly measurable, however, the resulting performance of the order, as given, is a valid indicator that the order was heard).

Thus, in response to measurement objective 1 above, the appropriate measures of performance should be the same or similar operational measures that are used to evaluate ARTEP performance, namely the Subtask Standards described within the ARTEPs. In most cases, these ARTEP measures are qualitative judgments (not quantitative as suggested in measurement objective 3 above), made by observers that answer the general question "Did the soldier perform the required activity?" and in some cases "within a specified time" or "within a specified sequence." Therefore, the primary measure of performance in the proposed experiments and demonstrations would be ratings (e.g., "Yes/No" or "1 through 5") made by people observing the subjects perform the activities within the virtual space. Many of these measures would "roll up" linked intermediate cognitive activities.

Several categories of operational measures would be important for assessing the performance of near-term activities, including:

Accuracy of Communications by voice, gesture, and audio signal;

Orientation and Navigation on terrain with respect to battlefield landmarks and other personnel;

Procedural Compliance for operation of weapons and equipment;

Compliance with Doctrine/Orders in military operations;

Perceptual Performance in recognizing personnel, terrain locations, and combat events on the virtual battlefield.

The qualitative judgments of observers, which would be the primary operational measures of performance/effectiveness, are shown in Table 22.

Table 22 Qualitative Measures of Performance of Near-Term Activities

Activities	Measures of Performance/Effectiveness																			
	Orientation	Movement	Navigate (whole body)	Arms/Hands	Recognition (observer identifies)	Spoken Words	Sounds	Perception (performer identifies)	LOS to object(s) on battlefield	Areas/objects on terrain	Areas/objects on map	Location/type of sound(s)	People on terrain	Human behavior	Aimpoint	Distance	Read document	Manipulation	Operate equipment	Handle object	Follow procedure
Give verbal orders						1															1
Use password						1															1
Call in preplanned fire requests						1			1										1		1
Blow whistle for signal							1												1		
Hear orders						1						1									1
Operate radio or telephone						1													1		
Identify safe and danger area										1	1										
Perceive relative position of other units										1	1	1									
Visually search for enemy										1											1
Move in accordance with directions			1																		1
Give hand and arm signals				1									1								1
Aim and fire individual weapon									1	1		1			1				1		1
Maintain position relative to other personnel																1					
Aim and fire crew served weapon									1	1		1			1				1		1
Identify hand and arm signals														1							

Table 22 Qualitative Measures of Performance of Near-Term Activities (cont'd)

Activities	Measures of Performance/Effectiveness																				
	Orientation	Movement	Navigate (whole body)	Arms/Hands	Recognition (observer identifies)	Spoken Words	Sounds	Perception (performer identifies)	LOS to object(s) on battlefield	Areas/objects on terrain	Areas/objects on map	Location/type of sound(s)	People on terrain	Human behavior	Aimpoint	Distance	Read document	Manipulation	Operate equipment	Handle object	Follow procedure
Aim and fire M60 MG									1	1		1			1				1		1
Aim and fire M203 GL									1	1		1			1				1		1
Identify support position which will enable fire to be placed on enemy	1								1	1	1										1
Read standard military symbols on a map											1										
Perceive relative position of weapon fire									1	1		1				1					
Identify areas that mask supporting element fires	1								1	1	1	1									
Identify overwatch position	1								1	1	1					1					
Place crew served weapons in operation	1						1			1									1		1
Identify light-reflected from shiny objects										1											
Change rate of fire																					1
Identify glow from cigarette										1											
Fire flare to signal															1						1
Identify dead space	1									1											
Read CEOIs																	1				
Identify obstacles									1	1	1										

Table 22 Qualitative Measures of Performance of Near-Term Activities (cont'd)

Activities	Measures of Performance/Effectiveness																				
	Orientation	Movement	Navigate (whole body)	Arms/Hands	Recognition (observer identifies)	Spoken Words	Sounds	Perception (performer identifies)	LOS to object(s) on battlefield	Areas/objects on terrain	Areas/objects on map	Location/type of sound(s)	People on terrain	Human behavior	Aimpoint	Distance	Read document	Manipulation	Operate equipment	Handle object	Follow procedure
Arm hand grenade																				1	
Identify orientation of soldier's weapon or fire									1	1		1		1							
Identify flashes from enemy weapons									1	1		1		1							
Aim and fire LAW									1	1		1			1				1		1
Discern location within an area									1	1		1									
Read dosimeter scale																	1				
Set frequency on radio												1							1		
Aim, fire & track DRAGON									1	1		1			1				1		1
Hear own movement noise												1									
Identify firing positions in building									1	1		1									
Identify orientation of main guns on vehicles									1	1		1		1							
Discern direction enemy is moving									1	1	1	1				1					
Place LAW in operation	1						1			1									1		1
Prepare DRAGON sight															1				1		1
Total of each Measure	6		1	1		5	3		18	25	8	18	1	4	8	4	2		13	1	19

Quantitative measures are also available in the BDS-D environment as Protocol Data Units (PDUs) that are broadcast on the DIS network, and are recorded by the Data Logger. The quantitative measures of performance illustrated in Table 23 can be applied to the 44 activities to be investigated and demonstrated in the near-term. Off-line analysis of the PDUs can be conducted by the BDS-D Data Collection and Analysis System (Monday, 1992) to determine such measures as:

Time in the exercise that the activity occurred. The time may be further decomposed into start and end times.

Position of the soldier, weapon, vehicle, or object on the battlefield (expressed in terms of the 6 degrees of freedom as X (latitude), Y (longitude), X (altitude) and pitch, roll, and yaw or in terms his position and orientation relative to some object(s) on the database).

Heading (orientation) in degrees (from north) of the soldier's face, weapon, or vehicle.

Velocity, or speed of movement of an object, soldier, or vehicle.

Exposure. A measure of whether each threat can see, is aiming at, or has fired on each object.

Tracking. Most tracking is assumed to be compensatory, that is, either following an object with eyes or binoculars, or a gunsight. Aiming is a special case of tracking, assumed to be the tracking behavior for 1 second prior to weapon release (trigger pull). The primary error variable is average absolute circular error in degrees.

Firing. A flag and time stamp when each weapon is released.

Hit/Miss. Hit/Miss data as calculated by the simulation system. The intended target is recorded by the observer.

Field of View of every bunker or vehicle window, porthole or weapon sight (or sensor), and of every soldier.

Table 23 Quantitative Measures of Performance of Near-Term Activities

Priority	Activity	Measure of Performance								
		Time	Position	Heading	Velocity	Exposure	Tracking	Firing	Hit/Miss	FOV
			1	3	4	5	7	8	9	11
1	Give verbal orders									
2	Use password									
3	Call in preplanned fire requests									
4	Blow whistle for signal					•				
5	Hear orders									
6	Operate radio or telephone									
7	Identify safe and danger area		•	•		•				
8	Perceive relative position of other units		•	•		•				
9	Visually search for enemy		•	•		•				•
10	Move in accordance with directions		•	•	•	•				
11	Give hand and arm signals		•	•		•				
12	Aim and fire individual weapon		•	•		•	•	•	•	
13	Maintain position relative to other personnel		•	•		•				
14	Aim and fire crew served weapon		•	•		•	•	•	•	
15	Identify hand and arm signals		•	•		•				•
16	Aim and fire M60 MG		•	•		•	•	•	•	
17	Aim and fire M203 GL		•	•		•	•	•	•	
18	Identify support position that will enable fire to be placed on enemy		•	•		•				
19	Read standard military symbols on a map									•
20	Perceive relative position of weapon fire		•	•		•				

Table 23 Quantitative Measures of Performance of Near-Term Activities (cont'd)

Priority	Activity	Measure of Performance								
		Time	Position	Heading	Velocity	Exposure	Tracking	Firing	Hit/Miss	FOV
			1	3	4	5	7	8	9	11
21	Identify areas that mask supporting element fires		•	•		•				
22	Identify overwatch position		•	•		•				
23	Place crew served weapons in operation		•	•		•				
24	Identify light-reflected from shiny objects		•	•		•				•
25	Change rate of fire									
26	Identify glow from cigarette		•	•		•				•
27	Fire flare to signal		•	•		•	•	•		
28	Identify dead space		•	•		•				
29	Read CEOIs									
30	Identify obstacles		•	•		•				
31	Arm hand grenade									
32	Identify orientation of soldier's weapon or fire		•	•		•				
33	Identify flashes from enemy weapons					•				•
34	Aim and fire LAW		•	•		•	•	•	•	
35	Discern location within an area		•	•		•				
36	Read dosimeter scale									•
37	Set frequency on radio									
38	Aim, fire & track DRAGON		•	•		•	•	•	•	
39	Hear own movement noise									

In addition to the qualitative judgments made by the observers and the quantitative data recorded during the conduct of a vignette, a post-exercise questionnaire will also be used for the subjects to:

Rate the sense of immersion in the virtual environment;

Identify any "disrupters" or "glitches in the simulation" that caused the participants to be reminded they were in a simulation;

Identify instances of disorientation or discomfort; and

Note any encumbrances caused by the devices in the ICS Testbed that interfered with their ability to perform the activities.

Finally, subject matter experts should also be asked to rate the ability of the selected virtual environment technology to

support each activity. Such subject matter experts (e.g., experienced military personnel from the Directorate of Training (DOT) of the Infantry School and the Special Warfare Center) would be asked to perform each of the identified activities, and to then rate (e.g., a 5 point rating scale) the degree to which the virtual environment could be used to perform and train the activity.

Subjects. The activities identified herein are the constituent elements of ARTEP tasks that are performed by military personnel. Most, if not all, of the activities require underlying skills that cannot reasonably be assumed to be available to non-military personnel (e.g., read a map, move tactically, etc.) The underlying military skills are those that are taught to all incoming Army enlisted personnel in Basic Training. Thus the subjects should be drawn from a pool of soldiers that have completed Basic Training. Furthermore, for the initial experiment of performance in the virtual environment, the subjects will be assumed to have already learned the activities to be performed. Thus, the initial subjects should have completed the Advanced Individual Training (AIT) course.

To provide a common baseline of entry-level skills, and to eliminate those persons who do not meet minimum requirements, the potential subjects should be screened prior to selection for participation. The Virtual Environment Performance Assessment Battery (Lampton, Bliss, & Gibbons, 1992) should provide the appropriate pre-test screening of the ability to operate in virtual environments. Subjects should also be excluded who are: (a) color vision impaired or whose vision exceeds 20/20 (uncorrected or wearing contact lenses; (b) hearing or speech impaired; or (c) physically challenged (e.g., have restricted limb movement). Subjects should be selected from the general population having the same characteristics and prior experience as the population to which we are predicting. The selection criteria for Infantry and Special Operations personnel who are likely to perform the ARTEP activities under study should be applied in the selection of test subjects.

Experimental Designs. The experimental designs suggested for the near-term experiments include the near-term activities as within-subjects variables clustered into the three vignettes, which is a between-subject variable. All technology attributes are examined as between-subjects variables. Experiments 1.1 and 2.1 will be two-factor designs, with the near-term activities (within-subject variable) clustered into three between-subjects vignettes. For experiment 1.1, 36 subjects will be used, grouped into three groups of 12 subjects each, each subject performing each of the activities within the specific vignette, with 10 trials per vignette. The number of subjects in all subsequent trials will be determined on the basis of the variance demonstrated in experiment 1.1.

Experiment 1.2 will include one within-subject factor (repeated measures on each activity within the vignettes that can be performed), one between-subjects factor with three levels (three vignettes, with 10 trials per vignette), and six between-subjects factors with two levels for each factor. Given this number of between-subjects factors, a full factorial design becomes untenable. To provide a more manageable design, a quarter-replicate 3 x 2^6 fractional factorial design is suggested. In this case, all main effects and some of the second-order interactions can be estimated, but all higher-order interactions are purposely confounded (Cochran and Cox, 1957, pp. 275).

Experiment 2.2 will include one within-subject factor (repeated measures on each activity within the vignettes that could be performed in experiments 1.1 and 1.2, 10 trials per vignette) and two between-subjects factors, with three levels each (three vignettes and three groups). That combination of technology attributes that demonstrated the highest level of performance will be used, with three groups performing as follows:

> The first group will be instructed to perform the activities in the ICS Testbed, and will then perform the activities in a real-world terrain area that is similar to the virtual terrain area.
>
> The second group will only perform the activities in the real-world terrain area.
>
> The third group will perform unrelated activities in the ICS Testbed, and will then perform the activities in the real-world terrain area.

Experiment 3.1 will include one within-subject factor (repeated measures on each activity within the vignettes that could be performed in experiments 1.1 and 1.2, 10 trials per vignette) and two between-subjects factors (three vignettes and Immersion vs Manipulation).

The experimental designs for the near-term experiments are summarized in Table 24.

Table 24 Experimental Designs of Near-Term Experiments

Experiment No.	Experiment Focus	Subjects	Independent Variables	Subject Factor	Experimental Groups
1.1	Activities that Can be Performed in VE	AIT Graduates	Near-Term Activities within a Vignette	Within Subjects	
			Vignette of Activities	Between Subjects	Three Groups
1.2	VE Attributes Contributing to Performance	AIT Graduates	Near-Term Activities within a Vignette that can be Performed	Within Subjects	
			Vignette of Activities	Between Subjects	Three Groups
			Display Type Display Resolution # Scene Polygons Terrain Resolution Auditory Localization Control Device Type	Between Subjects	16 Groups
2.1	Activities than Can be Trained in VE	Basic Graduates	Near-Term Activities within a Vignette that can be Performed	Within Subjects	
			Vignette of Activities	Between Subjects	Three Groups
2.2	VE Attributes Contributing to Training	Basic Graduates	Near-Term Activities that can be Performed	Within Subjects	
			Vignette of Activities	Between Subjects	Three Groups
			VE experience: 1 Train in VE then Transfer to Real-World 2 Perform only in Real-World 3 Unrelated tasks in VE the Transfer to Real-World	Between Subjects	Three groups
3.1	Immersion in the Virtual Environment	Basic Graduates	Near-Term Activities within a Vignette that can be Performed	Within Subjects	
			Vignette of Activities	Between Subjects	Three Groups
			Immersion vs Manipulation	Between Subjects	Two Groups

Mid-Term and Far-Term Research and Demonstrations

The same research issues that are examined during the experiments and demonstrations with the near-term activities would apply to the research and demonstrations to be conducted with the mid-term and far-term activities. However, the focus of these latter experiments would change to: (a) filling in the gaps in knowledge and technologies; and (b) expanding the range of individual ARTEP tasks that can be supported in virtual environments. This latter objective would be accomplished by demonstrating the performance of the activities in the mid- and far-term, which can then be combined with the activities demonstrated in the initial experiments into complete ARTEP tasks.

Expansion of Research Focus

Anticipated Requirements of Virtual Environment Technology

The anticipated requirements imposed upon the technologies that create and facilitate virtual environments have been implied earlier in the previous discussion of the activities to be supported in the mid- and far-term. That discussion highlighted the general technology areas that become increasingly important as we focus more closely on the unique requirements of individuals performing in a virtual environment. Primary among these more stringent technology requirements is the need to allow relatively unconstrained movement of an individual in a virtual environment. Such movement includes traversing across relatively large areas of the virtual space, crawling as well as moving upright, and moving around obstacles and across uneven terrain.

Precise and accurate tactile and force feedback also become increasingly important technology areas to be included in virtual environments in the mid- and far-term. These activities typically require dismounted combatants to manipulate and feel critical features of the virtual world, including terrain elements as well as equipment and weapons.

Visual and acoustic display requirements also become more demanding in the mid- and far-term; however, the required technical advances in these areas are evolutionary (e.g., higher resolution, faster scene generation, etc.), rather than the revolutionary advances that would be required in the movement, tactile, and force feedback areas.

Plan for Exploiting Anticipated Developments

With the increasing technical capabilities that are anticipated in the out years, it would be possible to demonstrate

the performance of the mid- and far-term activities listed previously in Tables 15 and 16. When the performance of these mid- and far-term activities can be demonstrated in a virtual environment, it would then be possible to combine the activities and to perform ARTEP tasks in the virtual environment. At that point, it would be possible to create scenarios in which individual dismounted combatants are issued military orders and who then conduct tactically meaningful missions.

As in the initial experiments and demonstrations, we propose that the future experiments and demonstrations be conducted as a series of vignettes that combine the near-term activities demonstrated in the initial experiments with the mid- and far-term activities shown in Tables 15 and 16. However, rather than being simply a clustering of activities with similar technology demands and with similar performance characteristics, these later vignettes would also be clusters of activities that constitute most, if not all, of one or more ARTEP tasks. These vignettes would thus be militarily meaningful missions to be performed by dismounted combatants on the virtual battlefield. However, because the availability of the supporting technology cannot be anticipated with sufficient accuracy at this time, it is inappropriate to define the specific content or sequence of vignettes now.

Given the revolutionary developments that would be required in some supporting technologies (and the concurrent possibility that such revolutionary developments may not occur in a timely manner), an area for study is the degree to which real-world elements can be combined effectively with virtual elements to create a seamless simulation of a tactically realistic battlefield. For example, it may be more cost and/or training effective to include actual objects (i.e., weapons, terrain obstacles, etc.) in the simulation, rather than relying solely on virtual objects. Thus, in addition to studying the performance of the activities (and combined activities in ARTEP tasks) in a strictly virtual environment, we suggest that the future experiments also include combinations of real-world elements with virtual elements in the vignettes.

Equipment Requirements

The complete suite of equipments required to support the performance of the activities from Tables 14, 15, and 16 in the virtual environment are described in next chapter. As noted above, until some capability is provided to allow the research participants to move through an extended space in the virtual environment, some mechanism(s) must be also provided to move the dismounted combatants' icons from one location to another in the virtual environment.

Staff Requirements

The staff that would be required to prepare for and conduct the proposed series of experiments and demonstrations would vary across the series of experiments. Initially, virtual environment technologists (i.e., hardware, software, and systems engineers) would be required to develop, procure, and assemble the constituent elements of the laboratory. As the experiments and demonstrations commence, behavioral scientists and personnel familiar with dismounted military operations would be required. As the initial experiments continue, the role of the engineers and technicians would change from procurement and development to maintenance and experiment support.

With the commencement of the second series of experiments and demonstrations, the role of the engineers and technicians would again focus on development, procurement, and assembly of the virtual environment technologies, while the role of the behavioral scientists and military personnel would focus on data analysis and reporting. This cycle would continue through the entire series of experiments and demonstrations.

Although the roles would be somewhat cyclical throughout the course of the experiments, demonstration of the currently available technologies and laboratory capabilities would be a constant function to be performed in the laboratory. Such demonstrations would certainly require the participation of the technical staff to prepare for and support the demonstrations. However, the focus of the experiments (indeed the focus of the laboratory itself) is on the behavioral requirements of training and rehearsal that are imposed by dismounted operations on virtual environment technologies. Thus, the demonstration and explanation of the laboratory capabilities must be conducted by the behavioral scientists and military personnel.

Table 25 lists the personnel that would typically be required to conduct the experiments and demonstrations in the ICS Testbed.

Table 25 ICS Testbed Personnel

Position	Description
Research Director	This person must have experience in experimental design and in the conduct of force-on-force experiments in the Distributed Interactive Simulation arena. Typically, such a person will have an advanced degree (M.A. or Ph.D.) in Experimental Psychology. The Research Director may also have prior military experience, although this is not a requirement.
Scenario Developer	A scenario developer will be required to define the specific actions that should be performed in the ICS Testbed, and to identify the activities to be performed in the real-world terrain area.
Observer(s)/Data Collector(s)	One or more observers will be required to observe and score the performance of the subjects in the ICS Testbed. The observers should have prior military experience, and should be experienced in observing and rating the performance of ARTEP exercises, such as Situational Training Exercises (STXs).
Systems Technician(s)	One or more systems technicians will be required to set up and to maintain the equipment in the ICS Testbed. Such personnel will typically be retired military technicians, and/or have an electrical, mechanical, or systems engineering education.
Software Engineer(s)	One or more software engineers will be required to author the ICS Testbed exercises, and to make any necessary additions/changes to the Testbed software.

FUNCTIONAL SPECIFICATION FOR A HUMAN PERFORMANCE RESEARCH TESTBED

Introduction

This section will define the operational configuration of the Individual Combatant Simulation (ICS) Testbed in order to:

Provide a clear visualization of what the ICS Testbed should be and what it should do, in operational rather than engineering terms; and

Provide the implementers with an explanation of what is needed in terms of system functionality, sufficient to allow them to produce hardware and software specifications. This includes:

A top-level system architecture, at the block diagram level, showing the general composition of the system in terms of hardware, software and data base elements.

A general description of the testbed physical layout.

A description of Testbed components as required to support the research plan in its initial operational configuration and at the block 1 and block 2 upgrade points.

The Functional Specification does not, however, specify in detail how the functionality is to be supported internally; that is left to the engineers and computer scientists who use the document as a guide to implementation of the system in hardware and software.

This Functional Specification will be a living document, in that it will need to be frequently revised as the design evolves during implementation of the ICS Testbed, both to reflect lessons learned during the course of development and to define compromises that inevitably will be required when desired functionality becomes difficult or impossible to achieve due to cost, schedule and/or technological constraints.

Assumptions and Limitations

The assumptions in developing this Functional Specification include the following.

The ICS Testbed will be designed and produced to commercial standards with respect to documentation, hardware, and software components, and will incorporate commercial-off-the-shelf components to the maximum extent possible.

The ICS Testbed will be used both stand-alone and interfaced to other DIS-compatible simulations, especially BDS-D.

The ICS Testbed will be operated and maintained by contractor personnel dedicated to that task in support of ARI experimenters, who will be its primary users.

The ICS Testbed will be implemented in three phases: (a) Initial Operational Capability (IOC), probably at the end of year one; (b) Block I Upgrade, probably complete by the middle of year three; and (c) Block 2 Upgrade, probably complete at the beginning of year five. Within each block, modifications will be prioritized based both on the requirements of the Research Plan and the engineering and cost effectiveness of combining or implementing them in a particular order. Feedback from the engineering considerations with respect to prioritizing upgrades will, in turn, be provided to scientists finalizing the Research Plan and may result in fine tuning of that plan.

Purpose of the ICS Testbed

During the past few years, research at government, academic and industrial laboratories has begun to produce tools for creating the kind of virtual environment experience that Individual Combatant Simulation (ICS) will require. Focused primarily on development of novel human-computer interaction techniques, and user interfaces for remote presence (telepresence and teleoperator) systems, these experiments have yielded both knowledge and specific devices facilitating the direct coupling of the human body and senses to virtual environments.

The experiments and concept demonstrations have been impressive in their implications of the power of future virtual workplaces and practice environments. As a practical matter, however, the individual environments and interfaces created to date are all deficient in terms of the richness of cues and the range and reactivity of the response sensing mechanisms. They have also been technologically rather than behaviorally focused; that is, they have focused on showing what can (and cannot) be done in this area, rather than looking at what needs to be done in a particular domain.

The situation that now exists is analogous to that in the early 1970s with respect to engagement simulation. The operational requirement has been articulated, and a technology

that seems, intuitively, to support its fulfillment is being developed. However, the detailed, performance-based requirements for that technology in application have not been identified, nor has the training strategy evolved and training management plan been developed that will be necessary to make ICS an effective addition to the training arsenal. In the latter regard, it is often noted that MILES employment is not engagement simulation. Engagement simulation consists, rather, of the execution of exercises, designed based on specific tasks, conditions and standards, during which performance data are captured, and after which prescriptive feedback is provided in the form of After Action Reviews. A similar context must be developed in which to apply the ICS.

The ICS Testbed, and the experiments it supports, will provide ARI a means to bridge these gaps for the Army and to focus the efforts of the technology developers, just as EFFTRAIN, SCOPES and REALTRAIN did in the 1970s for engagement simulation. Because of its modular design, the testbed will be able to keep pace as the technology improves and to change its orientation as new issues are raised, either as the result of experiments or in response to additional Army requirements.

Simulation System Configuration

The testbed will consist of one or more rooms containing a series of workstations and related computational and data collection/analysis equipment. The workstations will include several stations for experimenters and system operators, but the centerpieces of the testbed will be (initially two) Individual Combat Simulation (ICS) systems. These workstations will provide the instrumentation and cue generation devices necessary to project individual soldiers into a virtual battlefield. Each ICS will be networked so that collectives of soldiers (initially two) can perform tasks in concert. Figure 3 generically diagrams the testbed in a possible layout of the testbed. Fiscal and facilities considerations may dictate some other actual arrangement. All of the nodes shown on the diagram are discussed and defined later in this document.

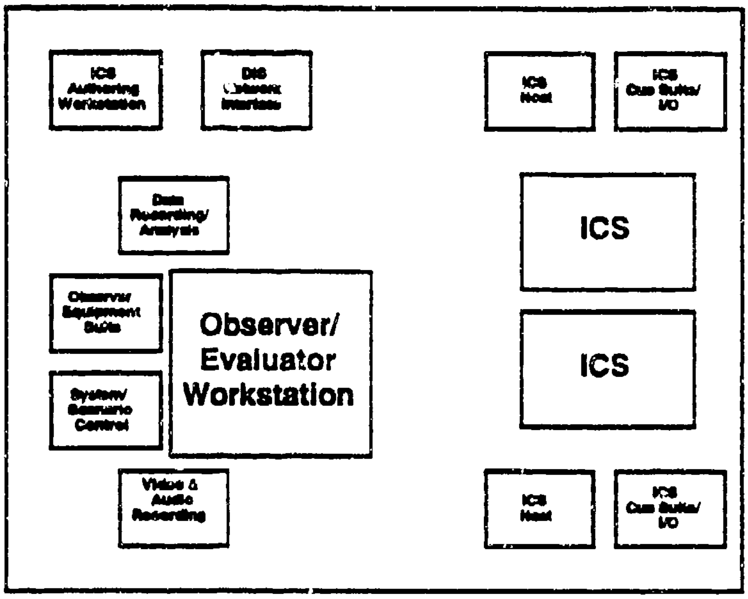

Figure 3. Notional ICS testbed configuration.

Evolutionary Development

This first iteration of the Functional Specification will define the system in three phases of its development: Initial Operational Capability (IOC); Block I Upgrade; and Block 2 Upgrade. Within each block, the modifications will be prioritized based both on the requirements of the Research Plan and the engineering and cost effectiveness of combining them or implementing them in a particular order. Feedback from the engineering considerations with respect to prioritizing upgrades will, in turn, be provided to team members finalizing the Research Plan, and may result in fine tuning to that plan. For reasons noted above, this initial document will contain detailed descriptions of the IOC Testbed and only general discussions of the Block 1 and Block 2 upgrades. Subsequent updates to the Functional Specification, produced in preparation for implementation of the upgrades, will support the final version of the research plan completely.

Required Operational Capability

System Functionality

Previous military training simulators were developed to represent crew stations in a vehicle. In the ICS Testbed simulators, however, the vehicle will be the participant's own body. This raises some difficulties not previously encountered, in that the displays or other cueing mechanisms must represent the relevant subset of all the direct sensory input received by a human being from the entire physical world (as opposed to an insulated compartment within it). The range of required control input mechanisms is indeterminate, at least initially. On the

other hand, some of the requirements normally associated with vehicle simulations do not constrain us here. Specifically, it may not be necessary to worry about modeling the vehicle dynamics and the fidelity to which they need be modeled, since we are using the real vehicle, the soldier, in the simulation.

The testbed will, therefore, require a highly anthropocentric design focus. That is, it must be built from the human participant outward, since the purposes of the proposed simulation's hardware and software are to:

Stimulate specific human behaviors (by providing perceptual cues);

Sense the observable human behaviors executed in response to the cues;

Convey the effects of these human behaviors to both the person who executes them and to other (networked) participants in the simulation as subsequent cues; and

Collect performance data with respect to both the behaviors and the enabling simulation suite.

Functions to be Supported

The ICS Testbed will support immersion of individual soldiers in a virtual environment which represents those attributes of the battlefield with which they must interact to execute selected ARTEP and Soldiers' Manual tasks and subtasks. The portals into this virtual environment will be a series of networked individual Combat Simulations (ICS). Each ICS will consist of one or more computers that drive a variety of instrumentation and cueing devices with which the soldiers who are experimental subjects will interact. The ICSs will be digitally linked together (much like SIMNET and BDS-D distributed simulation devices) so that soldiers can perceive each others' actions and reactions with the virtual environment, as well as their own, as they execute individual and collective tasks.

The ICS testbed will be assumed to be operable either as a stand-alone resource or as a collaborating node on the DIS network. Accordingly, the testbed must provide all of the functional capability essential to simulation support of the selected target activities, and must in addition be configured in such a way as to accept externally generated DIS interfaced combat entities as participants in the test scenarios. This has two implications.

First, the testbed should be designed as a standard DIS cell as defined under the BDS-D architecture, and interconnected with the DIS network through a cell interface unit (CIU). Standard

DIS cells are aggregations of simulations that utilize the DIS protocol for communications within the aggregate as well as for exchanges of protocol data units with the balance of the network. This convention greatly simplifies the network interface and reduces the development risk as compared with utilization of internal protocols that would require translation at the interface.

Second, the collateral forces and targets which are required to support the selected demonstration activities must be provided either through the participation of additional human participants or by semi-automated forces. Humans can enter the ICS virtual battlefield only through the portals provided by additional ICS player stations in the testbed, or by means of manned simulators collaborating over the network. Both options are considerably more expensive in terms of hardware and personnel support cost than utilization of semi-automated forces, which can also be provided either as a integral component of the testbed or remotely from another networked BDS-D facility. Co-location of the testbed with an existing BDS-D installation obviates the issue and provides maximum flexibility. If this is not possible, serious consideration ought to be given to equipping the testbed with a semi-automated forces workstation so that research can be conducted without depending upon the synchronous collaboration of outside network resources.

ICS instrumentation may include visual, sound, tactile/force-feedback, kinesthetic and (eventually) chemical cue generators, as well as sensors that detect the soldier's bodily movements (to include rates and force of head, limb and digit movement, eye movement and the like), and verbalizations. Sensors and cue generators will be a mix of equipment, some of which the soldier will wear and some of which will be off-body in his immediate vicinity. Of the latter, certain items will be manipulated by the soldier and others will either present cues or sense his actions without coming into direct physical contact with him.

The ICS Testbed will also provide tools for researchers to observe and interact with the experimental subjects, providing windows into the virtual environment and controls to alter it as appropriate to the experiment in progress.

The ICS Testbed will provide tools for constructing an exercise scenario, that is, for selecting the virtual battlefield on which the exercise is to be conducted and establishing the initial conditions thereon.

Finally, the ICS Testbed will provide local or remote access to data capture and analysis tools that allow investigators to define and collect measurements during the course of experiments

and to review/replay activities of subjects after the fact, as well as to conduct statistical analyses of the data collected.

Evolution of System Capabilities

The ICS Testbed will be developed as an open architecture system from the outset, in recognition of the fact that it will be an ever-changing and expanding facility, paced by the evolution of technology in the marketplace and the lessons learned by experimenters as this technology is investigated. The ICSs will be designed using commercial standard interfaces and modular designs. Modularity will be especially important in the design of cue generators, sensors and effectors and their interfaces with the rest of the system.

Components must be reconfigurable from experiment to experiment, and components (software and hardware) procured or developed for early versions of the system must be replaceable by those of greater capability that become available later with an absolute minimum of effect on remaining system components. An approach similar to that developed under the MODSIM[1] and BDS-D[2] programs must be used to achieve these goals, even at the sacrifice of some initial capability or incidence of additional initial cost.

Composition of the Virtual World

The ICS testbed will project test subjects into a virtual world designed to facilitate the performance of the prioritized demonstration objective activities identified in the research plan. This section discusses the general design requirements for

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[1] MODSIM is a generic modular simulation system architecture developed under Air Force contract number F33657-86-C-0149 by the Boeing Company. The design approach partitions simulation functionality into a series of modular components that communicate with one another using standard protocols. The architecture is intended to facilitate recurrent upgrade to the simulation system at minimum cost. The functional partitioning isolates independent processes so that changes to one do not produce "ripple effects" through the balance of the software system.

[2] BDS-D or Battlefield Distributed Simulation - Developmental is a DIS (IEEE STD 1278) based simulation architecture optimized for combat development applications. A product of STRICOM's Advanced Distributed Simulation Technology research project, BDS-D is intended to support rapid prototyping of conceptual weapon systems on an accredited virtual battlefield so that performance data collected will have predictive value to support development investment decisions.

that virtual world so that it is a suitable environment for conducting research on military behaviors. The next sections present the specific functional requirements, to include attributes of the virtual environment, imposed by the need to support the selected prioritized activities in the time frame specified. Requirements are discussed in logical aggregations of functions, not by proposed assignment of functions to hardware. A strawman hardware/software partitioning will be presented as a part of the testbed architecture described in the final section of this chapter.

The virtual world consists of representations of the terrain and things on it including dynamic entities (e.g., tanks, helicopters, enemy infantry, etc.). To predispose the simulation to produce high transfer effectiveness for training, or to achieve high levels of predictive validity for planning or rehearsal, these representations must react with the soldier to stimulate or constrain behavior as they do in the real world (Osgood, 1949). Therefore, they, like their real counterparts must have certain properties or signatures. For static objects in the virtual world, these include visual, acoustic, tactile, electromagnetic and thermal signatures. For dynamic entities, the same signatures must be produced and additional motion-related (e.g., seismic) signatures may be required as well. All terrain and solid objects must exhibit the natural attributes of impenetrability, rigidity, mass properties (weight, weight distribution, and their consequences - center of mass and moments of inertia), color, reflectivity, temperature, and surface characteristics such as friction. Liquids and gases represented in the virtual environment must also be depicted with physical characteristics and behaviors corresponding to their real world counterparts so that their influences on behavior on the virtual battlefield are appropriate.

The more complete and accurate these signatures are, the more effective the simulation can be expected to be for planning, training, and mission rehearsal purposes. While it may not be technically feasible at this time to generate such cues with a high degree of realism, it is appropriate to describe the desired signature environment as an end goal toward which a mature ICS should evolve.

Environment Database

Regardless of the activities conducted upon it, the virtual battlefield must be constructed with certain basic attributes so that it is a suitable environment for the conduct of real-world counterpart behaviors. These attributes include physical configuration and appearance, and virtual world physics and the dynamic behavior of objects within it. The encapsulation of the

structure and rules of behavior for the battlefield terrain and the objects that populate it is referred to in the following as the environment database.

The environment database includes characterization of the terrain and things on it, to include natural/man-made objects. It can be classified in terms of relief (altitude variations), drainage (water), vegetation (anything that grows on the terrain) and cultural features (fixed man-made objects). To support infantry operations in testbed research, the database must satisfy certain generic criteria.

Relief. The depiction of the virtual terrain relief must meet the following requirements:

Visual signature: Close in terrain relief must be sufficiently granular to allow a man to find, recognize, and utilize terrain cover and concealment. This implies that the undulations in the ground be clearly defined. Smooth surfaces with a continuous slope over long distances are not sufficient to support soldier interaction with local terrain. Pronounced irregularities at a scale of three feet (preferably less) must exist. Distant relief must be sufficiently visible to provide navigational cues at distances that the naked eye can usually perceive in daylight.

Audio signature: Real-world sounds, such as the crunch of boots on gravel or the snapping of twigs underfoot, should be provided both to enhance user belief state (sound is a very powerful and low-cost way to achieve this effect) and to make up for the scarcity of tactile cues to the nature of underlying terrain. The ability to insert bird/cricket sounds as well should exist, since these sounds, or the lack thereof, might be cues to the proximity of an enemy to patrolling soldiers.

Tactile signature: It will be necessary to provide the crawling or climbing soldier with the feel of the surface (e.g., texture, temperature, heat capacity, coefficient of friction, resilience) at bodily points of contact. For upright walking in combat boots only the slope of the terrain as the soldier negotiates it need be represented in tactile form. However, given the requirement for granularity in relief representation, this implies that the soldier perceive the presence of humps and wrinkles in the ground by feel as he walks across them.

Electromagnetic signature: Relief must interrupt light in the virtual world as it does in the real world.

Thermal signature: The ground has a generally uniform thermal signature. Anomalies such as spill from a recently dug foxhole, however, show a thermal signature different from the surrounding undisturbed soil. This subtlety is important for tasks involving concealed activity on the battlefield, whether the objective is to detect or to hide it. In any case, only the contrast need be shown. Modeling the actual thermal emissivity of the ground is unnecessary.

Drainage. The following drainage related cueing features are required to support realistic operations.

Visual signature: Water (streams, rivers, swamps) must be visible and clues to its depth, whether or not it is moving and how fast it is moving, should be visible as well.

Audio signature: The sound of running water should be presented when the soldier is within an appropriate distance. If the soldier is wading, corresponding splashing sounds should be provided.

Tactile signature: It will be necessary to provide the soldier with the feel of contacting liquid to support far-term demonstration objectives. Initially, however, tactile cues will not be required. Experimental subjects will be instructed to "follow the rules" when crossing water based on how it looks or sounds. If the test subject violates the rules in a way that in real life would cause him to sink or be washed away, these consequences will be depicted using visual and sound cues.

Electromagnetic signature: Significant influences of water, such as its effect on wire-guided ATGMs fired over it, must be modeled.

Thermal signature: Water has a uniform thermal signature that is different from the surrounding ground and must be presented that way. As long as appropriate contrast is achieved for visual presentations, the actual thermal emissivity of the water and ground will not necessarily have to be modeled

Cultural Features. Cultural features must be presented in accordance with the following:

Visual signature: cultural features must be clearly recognizable from appropriate distances and must have tactically significant features (e.g., buildings must have windows, roads must have shoulders, etc.)

Audio signature: The sound of boots on various surfaces differs. This difference can be used to cue the experience

of transitioning on to or off of pavement, or from one surface (pavement) to another (the floor inside a building).

Tactile signature: The soldier must be provided with the feel of tactile interaction with objects such as a building and with the feel of transitioning from walking on soil to walking on a hard surface.

Electromagnetic signature: Certain cultural features (power-lines, antennae, etc.) put out electromagnetic signatures. Only their effects on soldier-operated equipment need be modeled.

Thermal signature: Man-made objects have a variety of thermal signatures that are different from the surrounding ground and must be presented that way. As long as appropriate contrast is achieved for visual presentations, the actual thermal emissivity of the buildings, roads and the like will not necessarily have to be modeled. However, where buildings or structures are portrayed with lights on, the lights must show appropriate contrast and blooming with respect to the rest of the building.

Vegetation. The virtual battlefield must be populated with vegetation that provides:

Visual signature: Close-in vegetation must be sufficiently granular to allow a person to recognize and utilize it as concealment. This implies that in the foreground, trees and bushes of meaningful size be represented as individual visual icons. These should have the translucency associated with foliage (i.e. allowing one to peer through the branches without exposing oneself to the view of an enemy). Distant vegetation must be sufficiently visible to provide navigational cues at distances to which the naked eye can usually perceive in daylight. These cues include treeline locations, density of vegetation, etc.

Audio signature: Brush should rustle as the soldier passes through it, and twigs should snap underfoot. It is not necessary to model the individual branches or twigs acoustically to achieve this effect. Rather, generic sounds can be invoked as the soldier encounters various types of vegetation.

Tactile signature: It is necessary to provide the soldier with the feel of touching a tree or a bush or feeling branches and low growth as he moves through them.

Electromagnetic signature: Only the attenuation and reflection of the electromagnetic energy produced by a soldier's equipment needs be modeled (e.g., laser false

positives should be more frequent when lasing through vegetation than in open country).

Thermal signature: Vegetation presents a variety of thermal signatures that are different from the surrounding ground and must be presented that way. As long as appropriate contrast is achieved for visual presentations, the actual thermal emissivity of the foliage will not necessarily have to be modeled.

Other Entities

The ICS will project the members of an infantry unit (initially two soldiers) on to the virtual battlefield. However, in order to populate that battlefield with other meaningful tactically activity, the testbed must network with either a suite of other DIS simulators, such as at a BDS-D site, or with a BDS-D Computer-Generated Forces Workstation or equivalent system that places virtual robotic entities controlled by a single operator on the battlefield.

Existing and planned BDS-D entities must be recognizable by the ICS . This means that the icon library must be sufficiently large to display all of these players visually, and the ICS software must model the effects they broadcast on the network as they would be relevant to dismounted infantry. BDS-D entities may be driven by manned simulators, by Computer-Generated Force Workstations or by both; the interaction with the ICS (via PDUs) will be the same in either case.

Environmental Effects

Weather Effects. The ICS must be able to visually represent a variety of light conditions, from dark to broad daylight, as well as the reduced visibility produced by smoke, fog, dust, and rain.

Thermal Effects. A soldier using the ICS system must be able to operate in a night-vision goggles mode. As discussed above, the environment and other entities will present appropriate thermal signatures.

Electromagnetic Effects. The soldier's electromagnetic equipment (primarily radios) must interact with the environment and other entities as happens in the real world with regard to tactically significant parameters. The propagation of electromagnetic energy need not be modeled, only the effects. These include:

Signatures broadcast via PDUs over the network when the soldier is transmitting as to the frequency, power of transmission.

Attenuation by terrain and other obstacles.

Interference of other equipment operation (another adjacent radio on a close frequency, etc.).

Initial Operational Capability (IOC)

Tactical Tasks to be Supported

Appendix E lists the activities, the ARTEP tasks to which they relate, and their assignment to near-term (IOC), mid-term (Block 1), and far-term (Block 2) categories. Forty-four of the activities were identified as targets for IOC support. They fall into the general categories of: (a) visual, verbal and other audio communications activities; (b) activities involving the set-up and operation of individual and crew served weapons and equipment; and (c) activities involving the visual, auditory and tactile/force-feedback perception of tactical attributes of the battlefield cues (primarily visual cues).

System Functions to be Provided

The testbed and its networked support resources must collectively provide support for the functions listed in the following paragraphs. It should be noted that the break-out of functions does not imply a separate node for each set discussed. For the fielding of the testbed, the use of only one terrain/environmental database is required, and consequently there is not a requirement to select a database during any of the initialization procedures.

System Control. System control involves configuration of the testbed resources for a given experiment, initializing components, loading the appropriate data bases and software, and ideally, system performance monitoring and failure diagnosis. System configuration can be automated to some degree if development resources permit. The provision of an intelligent "simulation apprentice" or automated helper that inventories the simulation requirements of the scenario to be run, and configures the system to meet these requirements using an appropriate configuration of the testbed resources would be a useful option if the nature of the research requires frequent reconfiguration.

Whether automated to this extent or less sophisticated in implementation and therefore more demanding of human operational skills, it is essential that the operator interface be well conceived so that a minimum of specialized operational training and experience is required for investigators to effectively utilize the testbed.

Scenario Control. Scenario control incorporates the creation and control of computer-generated entities on the

battlefield (such as enemy units and platforms), the positioning of subjects in virtual space, the starting, stopping and freezing of an exercise and its associated data collection, and the ability to role play as necessary (e.g., act as a higher unit commander in radio communication with the subjects, respond to requests for supporting arms fire, etc.).

The Fort Hunter-Liggett terrain database is recommended for the ICS. This database is recommended because it is the only database known that is available in a terrain resolution of 1 meter. It also includes terrain appropriate for the conduct of all activities identified during the mission analysis, with the possible exception of urban terrain including building interiors. An upgrade to the existing Hunter-Liggett databases to provide such a practice area represents the minimum cost means to satisfy all ICS needs.

During scenario generation and control, specific scenarios will be configured with these data and with operational/mission-specific data. Initialization functions include: (a) selection of participants, weapon systems, and equipment; (b) structuring of lines of authority among participants; (c) placement of participating entities on the virtual battlefield; and (d) initialization of consumable supply levels and available supply rates.

Some part of the scenario control activity can be performed in advance and stored prior to experimental use of the testbed for later retrieval. For example, pre-established initial condition sets can be constructed and stored so that time on the ICS can be more efficiently utilized. Other functions of this workstation must be exercised in real time. The control of simulated adjacent and opposing forces, and the provision of role playing context for the virtual battlefield performance must be interactive with the moment-to-moment activity of the test subject. All of this implies that the scenario control console must be capable of both stand-alone operation and collaborative interaction with the rest of the testbed.

The scenario control console must provide a plan-view of the virtual battlefield that can be used as a reference tool for placement of virtual objects and personnel on the battlefield, and for development of operations overlays by annotating the map with control measures. This presentation should be similar to that provided at the SIMNET Stealth platform, and at the Semi-Automated Forces Command Stations in terms of functionality. The ability to reenter, pan, and zoom the map, and to selectively de-clutter it by excluding unneeded graphic elements would be a desirable feature for the display.

Remote resources on the DIS network can be used to support a portion of the ICS functional requirement. Semi-Automated

Forces, currently provided at several BDS-D testbeds, can instantiate dismounted infantry, armored and air threats on the virtual battlefield. A means must be provided to coordinate the initialization and interoperation of remote resources such as these in support of repetitive trials. Telephonic coordination with a remote operator is a simple but manpower intensive solution to this problem. A more sophisticated possibility may evolve, depending upon the direction taken in the development of the BDS-D semi-automated force component. Remote initialization and operation from the testbed scenario control station might be supported provided a requirement to do so is formulated and coordinated with the BDS-D development team.

Observation, Data Collection, and Analysis. Evaluation of the ICS technologies requires that research personnel have the ability to observe, measure, and analyze performance in both the real world of the laboratory, and the virtual world synthesized by the ICS. Observations must be possible from three points of view:

In the real space of the testbed, so that observable interactive behaviors of the test subject can be measured and studied as he uses the ICS interface controls and displays.

From an observer/evaluator perspective, the evaluators must be able to measure and study the task performance behaviors of the test subject as projected on the ICS virtual battlefield by his iconic representation. Evaluators must be able to move through virtual space and time to optimize observing conditions.

Evaluators must be able to share the cue experience and monitor response actions on the virtual battlefield from the test subject's viewpoint, so that performance variance can be allocated between the sufficiency of ICS enabling cues and response means, and the native ability of the test subject to perform.

These functions support the experimenters in observing the performance of subjects (from both a real-world and a virtual battlefield perspective), in collecting and annotating data during the conduct of the experiment, and in conducting post-experiment replays and data analysis. The DIS network will provide extensive capability to log and analyze activities on the BDS-D battlefield to which the testbed provides access. If co-located with such data recording and analysis resources in a BDS-D node, the testbed can be supported in its data acquisition and reduction requirements to a significant extent.

The observer/evaluator station should include the following.

Video capture and replay resources that can store imagery collected during experimental sessions and drive the observer/evaluator station displays during the data reduction process.

Displays presenting real-time or retrieved: (a) perspective views of the test subject(s) within the ICS testbed; (b) relocatable, directable remote views of the test subject(s) and their environs on the virtual battlefield; and (c) the views of the virtual battlefield environment as seen by the test subject(s) to include user's perspective of tools and equipment.

A plan-view display of the virtual battlefield centered on the location of the test subject(s) presenting terrain, tactical objects, representations of combat events, and utilities for situational analysis such as an intervisibility fan generator, zoom and pan controls, display de-cluttering options, position, direction, and distance determination tools, etc. An overlay annotation capability should permit observer/evaluators to mark and make notes on the terrain map for later use. Provision should be made for hard-copy output of the display including notation.

An observer/evaluator controllable cursor should be provided on each display as an overlaid symbol. This cursor should be usable to designate a particular object or line of sight direction in the perspective scenes, or a location on the plan view display. Utilities in the system should calculate identity, location, direction, and distance data in reference to designated screen positions, and facilitate entry of this data into the performance database for subsequent analysis.

A data recording and analysis display that permits the observer/evaluator to control the data logging process by interactively defining/selecting measures to be included in a performance database for examination by the system analytic tools. The observer/evaluator should be able to specify post hoc analytic processes to be used on the data from among the library included in the system. Results should be presented in tabular and graphical form, with hard-copy output available on demand.

An audio presentation and analysis resource that permits an observer/evaluator to experience, capture, and replay audio cues generated during the exercise, including both sound characteristics and localization cues. Replay should be synchronized to video retrieval.

A general purpose timing resource that can be used to mark visual and audio events, either in real time or during replay. A capability should be provided for determining time intervals between such event marks, and for entering all of the event and interval time data into the performance database for statistical analysis.

An intercom to the ICS station(s) to permit discussion with the test subject(s) as a part of the evaluation process.

Measures of effectiveness of performance and training in the virtual battlefield should be operational in nature so as to be comparable to evaluations conducted in field training of the same skills. Some of these measures are objective and quantitative, such as position, velocity, or heading error from a criterion value. Others must be subjective such as extent of compliance with doctrinal procedures. Generally, the testbed can be configured to readily supply pre-defined objective data for automated recording and statistical analysis. Subjective evaluation data collection, while possibly supportable by machine intelligence, is more flexibly and economically accomplished on the small scale of the intended research by expert observation and scoring. Thus the observer/evaluator workstation takes on considerable importance as an enabling component of the research operation of the testbed, and is not simply a gratuitous appendage to accommodate the curiosity of visitors.

Operational measures that will be important for the analysis of virtual battlefield performance for the near-term activities include:

Accuracy in incoming and outgoing communications by voice, gesture, and audio signal;

Orientation and navigation on terrain with respect to battlefield landmarks and other personnel;

Procedural compliance for operation of weapons and equipment;

Compliance with doctrine/orders in military operations; and

Perceptual performance in recognizing personnel, terrain locations, and combat events on the virtual battlefield.

Utilities for extraction of intra-interface measures will also prove to be useful. Three-space position of arm, hand, and fingers, posture and orientation of the body, and direction of line of sight may all be transduced in the ICS to properly envelop the user in the virtual surround. The time history of this information will constitute the real space response record;

this information can serve as the basis for evaluation of timeliness and correctness of action in tasks involving physical behaviors.

A variety of analytical tools must be provided, either as an integral part of the ICS testbed, or as a data compatible adjunct to it. As a minimum, the ICS should record specified performance data in time-correlated sequences. These data vectors must then be compiled into databases that can be interactively queried by a standard statistical package. Two kinds of analyses are envisioned: (a) predefined analyses producing real-time distillations of objective experimental data as it is collected; and (b) post-hoc analyses produced by statistical operations on the accumulated database and on subjective evaluations after objective data collection has been completed.

Objective measures must be captured in the recorded history of the activity trial, either in the network data traffic or extra-network recordings of subject behavior. Subjective evaluations based upon subject matter estimation or test subject testimony are developed post hoc on the basis of the recorded histories and test subject exit interviews.

To accommodate the former, evaluators should be provided with a menu of state variables (both logical and numerical) available both from within the simulation and from packet traffic over the DIS network connecting ICS to interoperating resources. The evaluator should be able to designate specific individual variables and combinations of data elements, and a desired sampling frequency associated with each[3], for statistical processing. In addition, the evaluator should be able to predefine the occurrence of significant events by characterizing them in terms of particular conditions of logical and numerical data. The history of instances and time of occurrence of such events must also form a part of the data record available for analytical treatment. Statistical operations likely to be needed for this class of analyses includes univariate and multivariate descriptive statistics (i.e. exceeding thresholds, distribution parameters, frequency of occurrence, correlation, and

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[3] Data collected with maximum temporal resolution will aggregate to very large databases quickly. It is probably not necessary to base statistical analyses on data samples collected at the frequency required to support computations sustaining the simulation. Thus, we recommend that the researcher be provided with the option to sub-sample the state data to produce experimental measures at operationally meaningful intervals (e.g., once per second, once per minute, etc.), rather than base analyses on the update rate of the state calculations (up to 15 per second in accord with the DIS standard).

covariance). Utilities must be provided for data visualization in tabular numeric and in graphical representations.

Post-hoc experiments are likely to be more complex and will therefore require more flexible and sophisticated tools. Evaluators must be given capabilities to define specific statistical tests sequentially as initial conclusions suggest follow-on questions. Interactive query of the captured test data must support the formulation and statistical study of complicated data interrelations. Experimental issues in these follow-on analyses will focus on relationships among variables as opposed to purely descriptive indicators. Thus analysis of variance, multivariate analysis of variance, factor analysis, paired comparison statistics (Linear and Non-Linear), multiple correlation, and multivariate linear and higher order regression capabilities will be important analytic instruments. Where ICS cueing and response performance levels are the independent variables in experimental investigation of support required to perform an activity in ICS, expressing results in the form of a response surface is more desirable than simply determining whether particular test conditions produce statistically reliable performance differences. The response surface characterization of results captures the continuity of relationship between test conditions and resulting performance in a format much more useful for the guidance of engineering design in the implementation of knowledge gained by the experiments. To provide for this possibility, response surface generation tools should be included in the analytical suite.

DIS networked data capture and analysis tools are not helpful in recording, replaying, and supporting the analysis of activities that take place in the real world[4]. Where investigators desire to examine the physical behaviors of test subjects outside the virtual environment, a suite of video and audio recording and replay equipment are required as an element of the ICS suite. The requirement for these components is driven not so much by the activities to be simulated as by the analytical techniques to be employed in execution of the research

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[4] The DIS protocol accommodates message traffic of mutual interest between simulated entities on the virtual battlefield, and between those platforms and control and data logging/analysis resources on the network. There is no provision in the protocol for the communication of individual crew member behaviors within platforms, nor of real-world behaviors of participating individuals even though transduced by the soldier-machine interface. When the present DIS protocol standard was formulated, there was no need to act on such data outside the simulator in which it is sensed, thus no defined process for its transmission. DIS does provide a Protocol Data Unit (PDU) that could be employed for this purpose, but only by local convention.

plan. Tools for analysis of subject behaviors in the real space of the ICS will be useful. These would include video editing functions such as a vertical interval timecode insertion/ reader system, videodisc storage and replay capability, a computer-interfaced video cursor insertion and position recording capability, a video overlay annotation function, and an audio timing and analysis system.

Individual Combat Simulation. For the foreseeable future, technology will not be able to provide a Star Trek Holodeck that totally immerses all of one's senses in virtual space. Therefore, the focus of the ICS must be on providing sufficient virtual cues for the performance of tasks to be trained. But consideration must also be given to the creation of a belief state in participants that they are actually in the virtual world, sufficient to overcome the cognitive dissonance created by conflicting (real vs virtual) and abstracted sense cues. In other words, the ICS must foster what dramatists refer to as "the willing suspension of disbelief." Certain design elements and cueing not directly auditable to the tasks-to-be-trained will be recommended for this latter purpose.

An examination of the near-term supportable activities in Appendix E suggests that the system should at IOC provide a set of ICSs with the following capabilities:

A visual system that allows soldiers to view task critical aspects of the virtual battlefield, and representations of self and each other on it with sufficient granularity to recognize friendly versus enemy soldiers and to recognize the body movements (to include fine detail such as gestures of the hand) and weapon orientation of fellow soldiers. The visual environment must also be populated with model representations of tools and weapons essential for performance of the activities selected to be the near term focus of the testbed.

A sound system that presents task-significant and contextually relevant battlefield sounds, to include a voice communication subsystem that allows the soldiers to talk to each other. Sound effect quality must be sufficiently good to permit recognition of unique weapon type audio signature, and to discriminate among weapon types in source localization. Sound localization cues must be presented to support identification of origin of weapons fire by audio signature.

A capability to recognize, and interpret, and to originate spoken messages to support the simulated communication among individual combatants and between them and virtual collaborators. This requirement can be met by role playing

actors who take the part of the virtual players in collaborative tasks.

Movement sensors, attached to or focused on the soldier's body, that transduce motions and gestures that when encoded and processed, enabling the soldier to move through the virtual world by means of natural body movements extrapolated and projected into virtual space, to include rotation and displacement.

Weapon effect signatures must be created so that muzzle flashes can be seen when simulated small arms are discharged by both the test subject and by virtual opponents (who may be semi-automated forces).

The ability to operate weapons and equipment and sense the effects of such operation in the virtual world. In the near term this would require either virtual or physical representations (props) and operational mathematical models for: (a) communications gear (whistles, radio transceivers and telephones); (b) weapons (rifles, machine guns, grenade launchers, flare launchers, hand grenades, LAW, DRAGON, and other crew served weapons); and (c) other equipment (dosimeter, compass). If modeled as entirely virtual objects, there is a need for high precision in visual representation and articulation of parts, with sufficient tactile and force feedback to enable realistic operation. If, however, the objective of the virtual experience is not training to operate these systems per se, but rather focuses on their use as a part of collective tactics employment, some latitude in the precision of virtual representation may be permitted. Since force-feedback and tactile cue generators are not expected to be well-developed technologies in the near term, this requirement may be met by providing the weapons and equipment as simple virtual approximations paired with physical props instrumented so as to have the effects of their operation transmitted properly to the virtual environment.

At least two interconnected ICS stations so that communications and mutual observation are possible.

ICS Authoring System. An ICS Authoring System will be used during a preparation phase of ICS usage to allow the creation of scenarios and databases. The former includes data to support the creation of the visual models and underlying operational algorithms for tactical objects, e.g., tools and weapons required to perform specific activities in the virtual world. The latter are the repositories of descriptive data configuring the virtual combat arena itself - the terrain and the cultural features that populate it.

Although equipped with special purpose software tools that make the modeling process very efficient, use of the authoring system will require specialized computer science skills not expected to be brought to the testbed by the behavioral research staff. Much of the original modeling might be performed by supporting contract personnel either on-site or at a contractor facility better equipped with technical resources for performance of simulation database development. However, the requirement for on-site database maintenance and modification still requires that the authoring station be provided as a part of the testbed, even if the original development is done elsewhere.

Block 1 Upgrade

At the conclusion of the near-term demonstration program, the testbed will be upgraded to Block 1 configuration in preparation for work with the mid-term activity objectives. These are more demanding in terms of visual cueing and require more mobility on the virtual battlefield than do the IOC demonstration activities. As with the near term configuration of the testbed, the upgrades required are driven by the nature of the simulation requirements.

Tactical Tasks to be Supported

The research plan identifies 44 prioritized activities that can be supported in the mid-term, and that occur in more than five of the 67 tasks, plus four critical but less-frequently occurring activities also selected for demonstration in the mid-term. These activities provide additional simulation challenges.

First, tactical movement across the virtual battlefield must be supported. Routes must be discerned that provide cover and concealment, movement by various methods facilitated (upright, crawl, rush), control of direction and rate of movement must be provided, and navigation with respect to battlefield landmarks and prepared plans supported.

Second, more sophisticated visual cueing must be provided to enable users to recognize differences among virtual personnel on the battlefield (friend/foe, military/civilian, identity, rank, etc.), to perceive subtle characteristics of the terrain (preferred routes, distant landmarks, estimated distance, fields of fire), and to view and interact with details of modeled objects (inspect equipment, administer first aid).

Third, tactile feedback may be required to support the grasping and manipulation of small virtual objects (attachment of wire, operation of chemical alarm, checking of radio instruments, set up of Claymore mines).

To meet these challenges, the testbed IOC capabilities must be extended by some addition of functionality and increases in specific levels of performance.

System Functions to be Provided

System Control. No substantive changes in the system control function are required to upgrade the testbed to the Block 1 condition. System control functions will continue to include:

Initialization of the presence and location of the individual combatant, his tools and equipment;

Initialization of other players (friendly and enemy, manned and semi-automated) and their combat systems on the virtual battlefield;

Configuration of the ICS user station to employ the correct set of cueing and response devices for the intended activities; and

Starting and halting data collection, recording, and replay.

The system control console will also be used to start and halt the simulation, to interact with the ICS processor(s) for cold start, and for hardware and software diagnostic procedures.

Scenario Control. The Block 1 upgrade to the scenario control station need only be a minimal one that enables the experimenters to include and initialize the additional personnel and equipment that play a supporting role in the investigated activities.

Observation, Data Collection, and Analysis. The observation, data collection, and analysis capabilities of the testbed will require some modest upgrade.

The enhanced cues available to the ICS test subject must also be provided at the observer station so that they can be shared by the evaluators. An escalating involvement of bodily movement and locomotion across the battlefield required by the mid-term target activities increases the importance of real-space surveillance of test subject physical action at the observer station. The complexity of small virtual object manipulation required by certain mid-term activities demands finer granularity in the imaging of the task performance space for evaluators so that a proper procedural evaluation can be conducted. Finally, the recognition of personnel and equipment based upon appearance (facial, clothing, rank insignia, etc.) and sound characteristics (signature, direction of origin, distance) as presented to the

test subject, demands a sophisticated graphics, sound generation /audio signal processing, and display (both visual and audio) capability be provided at the observation/evaluation station.

A wider range of performance measures, appropriate to the expanded inventory of demonstrated activities, is required. These include measures appropriate to the appraisal of tactical movement, identification of personnel and equipment, analysis of terrain, and procedural interaction with weapons and equipment. Measures must be of both a quantitative (e.g., position, speed) and qualitative (e.g., an event occurs) nature.

An expanded repertoire of analytical methods appropriate to the evaluation of performance of the additional activity set must be available. Interactive post hoc analysis using researcher defined analytical processes should be supported.

The observation resources of the IOC observer/evaluator station must be augmented so that the richer visual and auditory cues required to support performance of the mid-term activities are available to observers. Only in this way can observed behaviors be correlated to the initiating cues so that task performance variance can be allocated between subject capability and cueing performance of the ICS. The nature of the mid-term activity demonstration objectives requires that greater detail in the visual scene be provided to enable the subject to perceive such subtle visual details as facial features, small parts of weapons and equipment, wounds (for first aid treatment), and cover and concealment possibilities on the terrain. Any upgrade in visual image generation performance at the ICS must therefore be matched at the observer/evaluator station.

By the same reasoning, activities enabled by sophistication in audio cueing (e.g., accurate reproduction of real sounds, representation of direction of origin, etc.) require that evaluators be able to share the audio experience of the test subject to properly understand the basis for observed behaviors. Directionality of sound should be presented as it is displayed to the test subject. If the test subject turns his head, the evaluator should perceive that the source is rotating in the azimuth plane. A sound visualization capability (e.g., computer simulated sampling oscilloscope) that could be used to measure the time at which sound cues commence might be a useful assessment tool for activities involving detection based on audio cues.

Several of the mid-term activities involve manipulation of small objects or articulated parts of equipment. Performance of these activities will relate to the adequacy of tactical feedback in the ICS. Evaluators must be provided with tactical display(s) that enable them to experience the sensations cueing the test subject behavior. Signals driving these displays should be presented on a time-based visualization system so that, as in the

case with sound cues described above, evaluators can measure the temporal characteristics of tactical cues for inclusion in the statistical analysis.

Measures of performance for the mid-term include all of those defined for the IOC counterparts described above, along with a few additional tailored to the unique requirements of the target activities. These include:

> **Orientation** on the battlefield with respect to compass directions, mapped landmarks, terrain landmarks, control measures, and friendly and enemy activity. This implies situational awareness of location and line of sight direction with sufficient precision to assess compliance with preplanned intention. It further implies an ability to perceive and properly recognize battlefield orientation cues of visual or other nature.
>
> Ability to properly **interpret and correlate the battlefield map**, including control measures overlaid thereon. If generated as a virtual object, this measure will strongly reflect the quality of the graphic representation (e.g., granularity, color coding, legibility of symbols and text, etc.).
>
> Ability to **identify personnel** on the battlefield, and to classify them as to friend/foe, military/civilian, and level of authority based upon appearance of facial features, clothing (uniforms), rank insignia, voice characteristics, and on-going behavior.
>
> Ability to **identify combat systems** by appearance and sound cues.
>
> Proper techniques of movement to include considerations of tactical employment of cover and concealment, appropriate velocity, and accuracy of navigation and avoidance of obstacles to passage.
>
> Perception of visual aspects of virtual battlefield including ability to visually interpret terrain, to find cover and concealment, to identify clear lines of sight, to find and count tactical objects, to estimate their distance from the observer, and to read with accuracy from virtual text and equipment displays (e.g., compass, radio).
>
> Ability to manipulate small objects for assembly, disassembly, and operation of equipment. **Ability to carry virtual objects** with appropriate effects on collateral performance. **Ability to write** down information on virtual paper.

Adherence to proper procedures in equipment set-up and operation, in tactical decision making, and in administration of first aid to simulated wounds.

Mid-term requirements for analytical support ought to be accommodated by the IOC analysis package described above with minor extensions. An expanded range of measures in the evaluator's selection menu is called for to access the augmented collection of state variables and discrete events upon which statistical tests can be made. Procedural templates for activities and for the operation of combat equipment must be available so that observed behaviors can be either automatically or manually compared to the proper standard for evaluation. These templates should be developed on the observer/evaluator work-station for later reference by human or automated evaluators.

Individual Combat Simulation. To support the activities to be simulated in the mid-term, the Block 1 upgraded testbed must provide additional and more sophisticated cueing and response capabilities than are required at IOC. Specific functional extensions include:

An improved performance visual image generation system capable of creating a visual environment that supports battlefield surveillance over an area of interest /influence appropriate to a dismounted combatant. This implies an ability to see and discriminate features of the terrain and to recognize personnel and tactical equipment at distances exceeding the engagement range of weapons carried (± 500 Meters). These surveillance activities, as well as others that involve perception of relative motion of close objects (dismounting vehicle, move by low crawl) require a relatively wide field of view. At closer observation distances (< 5 Meters), fine detail such as unique facial features of personnel, battle wounds, and small parts of equipment must be discernible. Resolution and color rendition must be good enough to support identification and use of cover and concealment. Battlefield landmarks (peaks and ridge lines, treelines, roads, rivers etc.) must be recognizable and correlatable to maps to help with navigation and tactical orientation. Terrain and cultural features upon it must be presented at accurate scale, so that distance estimation on the basis of stadiametric measurement is correct.

An expanded capability audio cueing system that can replay/synthesize: (a) individually recognizable human voices (to include voice characteristics as well as language spoken); (b) unique equipment operation related sounds; and (c) battlefield ambient and activity related noise is required. A variety of activity related sound cues that can help with the identification of personnel behaviors must be

provided. Directional cueing is essential as a primary aid in orientation with respect to objects of audio attention on the virtual battlefield.

Provision of tactile displays that support: (a) the performance of assembly and disassembly of virtual equipment consisting of small parts; (b) the manual operation of virtual controls on combat systems; (c) the sensations associated with holding, carrying, using, or throwing virtual objects; and (d) the appropriate perceptions deriving from contact with the ground and surrounding objects (foliage, buildings, combat vehicles, etc.). Relatively low resolution tactile displays on the bottoms of feet, on the knees, on the stomach/chest, back, and buttocks will suffice to communicate contact with the ground and other environmental surfaces. Higher resolution tactile stimulation is required for the palms of the hands and fingertips to assist in the representation of the sensation of smaller objects and surface textures.

Furnishing a means to limit the range of bodily motions consistent with represented limits to movement in virtual space. Whether delivered by an articulated exoskeleton or other mechanisms, a reinforcement of the visual and tactile based perception of the impenetrability of virtual surfaces is required. Furthermore, a graduated capability to resist motion and thereby convey an impression of the compressibility and resilience of surfaces is desirable to enhance the uniqueness of object tactile signatures.

Additional virtual objects modeled to support the performance of the selected mid-term activities including: uniquely identifiable personnel; personal equipment; maps, charts, documents bearing text and drawings; writing instruments and paper; food, water, and ammunition containers; first aid instruments and supplies; protective mask; chemical agent detection gear; radiation detection instrument; demolition equipment and explosives; explosive and smoke generating hand grenades; trip wire activated warning devices and detonators; communications wire and telephone equipment; mountable/dismountable combat vehicle; and Claymore mines.

ICS Authoring System. The scenario authoring station must be upgraded to support development of an ICS virtual environment containing the subtler cues required to conduct the mid-term activities. For example, icons representing other battlefield personnel will at mid-term require recognizable faces and clothing, and must appear to be engaged in tactically meaningful behaviors (e.g., through animation or obvious operational relationship with combat equipment). Models of combat equipment that can be assembled and disassembled, and featuring articulated

parts that can be operated by the test subject in virtual space must be generated and supported. Virtual maps and written communications are required by certain of the target activities[5]. The authoring station must have tools for creation or importation of virtual maps, and modeling of written documents to include creation and formatting of text and illustrations.

Block 2 Upgrade

Tactical Tasks to be Supported

The research plan identifies (in Table 16) the 15 prioritized activities to be supported by the ICS testbed in the far-term (estimated to be technically supportable in 4-5 years). These difficult-to-simulate tasks impose significant challenges in visual, audio, tactile and kinesthetic cueing technologies.

> Activities to be supported in simulation include several that demand the test subject visually detect personnel and objects under very difficult observation conditions (e.g., through camouflage or foliage cover).
>
> Other activities involve excavation, construction, and elimination of signs of presence. Each of these requires movement of soil, either to create a depression or berm, or to smooth the surface to eliminate such human signatures as footprints. Highly granular dynamic virtual terrain is necessary to support these effects accurately, although functionally equivalent approximations might prove acceptable to perform training.
>
> Digging within and smoothing the ground demands high-resolution tactile and kinesthetic feedback.
>
> Visual and tactile perception of surface wetness (as occurs during chemical decontamination) requires real-time: (a) surface reflection generation; (b) directional light sources; (c) tactile display of temperature and heat capacity; and (d) changes in the amount of surface friction in dynamic interaction among objects.
>
> Greater sophistication in object modeling and tactile cueing will be required to permit the enclosure of one virtual object with another (e.g., seal small objects in waterproofing bags).

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[5] If technically stressful, these requirements can be acceptably met by maps, paper, and writing instruments in real space .

Substantial gains in virtual environment cueing and response transducing technology are required to advance the state-of-the-art to meet these requirements.

System Functions to be Provided

System Control. System control functions remain essentially unchanged from the Block 1 upgrade configuration. Re-initialization of the virtual terrain between trials may be required to reset the condition of sites where hasty or deliberate battle positions have been emplaced during trials. Similarly, the testbed controller may be required to restore tools and other objects to their original location and condition after use during a demonstration exercise in preparation for the next run. A restart capability will have to be provided to accomplish these actions.

Scenario Control. There do not appear to be any substantial functional enhancements required at the scenario control station to accommodate the Block 2 upgrade. Minor extensions should support:

Initialization of additional virtual tools and equipment that will be employed.

Repairs to the virtual terrain to restore the natural surface after simulated excavation or surface smoothing.

Repairs to terrain or objects that populate it after simulated explosion of demolitions.

Distribution of debris in a simulated LZ to stimulate clearing activity.

Chemical contamination of an area including its population of personnel and equipment to stimulate virtual chemical alarms and decontamination activity. Also required: a capability to dry-up liquid runoff after decontamination exercises.

Emplacement of camouflaged or foliage covered personnel and equipment search targets.

Initialization of stocks of food, ammunition, and fuel containers suitable for burial in a cache.

Initialization of a supply of virtual beams, sandbags, corrugated sheeting, and netting that can be used to construct overhead cover for a fighting position.

Observation, Data Collection, and Analysis. Observation, data collection, and analysis capabilities of the testbed after the Block 2 upgrade must provide the capability to see, measure, and evaluate performance of far-term activities on the virtual battlefield. Specific considerations for the far term include the following.

> Observers must have access to, if not the ability to directly share, the cue experiences of the test subject so that an evaluation can be made of the appropriateness and timeliness of responses. Attention must be given to the capabilities of the computer image generator at the observer's station to ensure that the increased performance required at the ICS is available for evaluators as well.
>
> Measures of activity performance should, as before, have an operational basis so that adequacy of execution can be evaluated in accordance with ARTEP guidance. Component skills, such as personnel detection, ability to use tools effectively, and the like, can be pre-tested in the ICS simulation, using constituent measures such as detection time, accuracy, and confidence, or time to accomplish the task, and subjective ratings of comparability with actual tool use, respectively. Once adequate confidence in the constituent cue/subject/response connectivity is established in the pre-testing, ARTEP Conditions and Standards may provide the reference for MOPs for the activities performed in their entirety.
>
> Analytic tools developed to support earlier experiments should suffice for the reduction of data collected after the Block 2 upgrade.

We have deferred the target activities of interest here to the far term because as a group, they involve human interaction with subtle details of the environment that cannot be simulated in the near foreseeable future. As these activity related observation problems are solved for the ICS, the solutions must also be implemented for the observer/evaluator.

Some are visual challenges, such as finding people and equipment deliberately placed in visual clutter that makes them hard to find. To simulate camouflage and battlefield cover realistically requires a visual system with very high resolution (so that small clutter objects can be modeled), very high polygon throughput capacity (so that an abundance of complex surface shapes can be rendered), and wide dynamic color range (so that subtle coloration differences can be resolved). These are a very expensive combination of performance requirements, but as the cost of computational capacity comes down, an affordable image generation resource capable of producing the type of imagery required may be realized.

Some involve support of intricate interaction with terrain elements that must reactively change in real time. Early experiments with dynamic terrain are on-going with promising results. Modeling the battlefield with the dynamic granularity required to enable a dismounted warrior to dig a foxhole one shovel full at a time, to account for the volume of soil removed, and to allow it to be reformed into a protective berm of the same bulk exceeds the capacity of current computers for detailed accounting of the state of the virtual battlefield. Most terrain models in use today cannot resolve the small object sizes involved[6].

Some require modeling support of interaction with virtual objects of considerable complexity. Consider, for example, the two activities that involve camouflaging a trail or fighting position. Doctrinal techniques for accomplishing this masking involve cutting and overlaying foliage to disguise cleared paths and emplaced firing positions. Modeling brush so that it can be cut, moved, and piled in real-time with realistic visual and tactile appearance in the process will stress the memory and/or computing capacity of the most powerful of present day super computers, not to mention the challenge to resolving capabilities of visual and tactile displays now available.

One requires visual and (possibly) tactile interaction with objects that can be made wet as a part of the execution of the activity. The wetting of the subject of chemical decontamination efforts changes not only its appearance (dull to shiny), but also how it feels, even through protective gloves. Objects that are wet are slippery and have higher heat conductivity and thus (if at a lower temperature than body temperature) feel colder than when dry. While the appearance and dynamic friction factors can be dealt with through increased computational speed in computers supporting the ICS using now known algorithms, technology for

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[6] The most detailed microterrain models in terrain imaging used to date employ 1 meter grid spacing for characterizing the surface of the ground. As grid spacing scale is reduced to, for example, 2.5 cm so that an object of about twice that size can be resolved, the volume of data required to describe a given terrain patch is increased by a factor of 1600:1 (40 X 40). Not only must 1600 times as much information be stored to characterize the terrain, but 1600 times as much data must also be swapped into active memory per given unit of time to support the rendering process. The image generator must be 1600 times faster in its rendering activity to depict a given terrain patch. If we assume an order of magnitude increase in performance every 2 years, it will still be optimistic to expect to achieve this gain within the planning horizon of the testbed.

simulating changes in virtual object heat capacity at the temperature slew rates that would have to be generated may not be available[7].

Measures of performance for the far-term activities include those developed on the testbed for the IOC and mid-term demonstrations, and in addition the following tailored to the evaluation of the target skills:

Perception of military personnel and equipment when masked by cover and camouflage,

Ability to disguise a battle position, trail, self, supplies and equipment using camouflage, excavation, and vegetation,

Ability to utilize digging and smoothing tools to excavate holes in the ground and to eliminate signs of human passage,

Ability to perform chemical decontamination wash-down of personnel and equipment, and

Doctrinal compliance in construction of fighting positions, chemical decontamination procedures, and clearing an objective.

Statistical tools provided for analysis of results observed during IOC and mid-term experiments on the testbed should be adequate to accommodate analytic requirements of the far-term testing.

Individual Combat Simulation. Cue generation and modeling capability at the ICS stations after the Block 2 upgrade will require substantial enhancement to support far-term activities. The computational demand imposed by the use of very high resolution databases, highly granular modeling of the terrain and objects upon it including tactile characteristics, and extreme detail in visualization in terms of resolution, dynamic range, and field of view will require significant upgrade to the computer resources of the testbed. Memory capacity, data flow rates, and computational rate will all need to be boosted well beyond performance available in today's commercial market to adequately support real-time operations. These requirements are driven by the need to provide:

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[7]There is an existing product that can display temperatures under computer control - whether the heat pumping capacity of the thermatrode display is sufficient to stabilize the temperature of a fingertip at the virtual temperature of the decontaminant liquid (even as perceived through insulating protective gloves) must be determined.

Sufficient visualization performance to generate visual clutter camouflage in a scale suitable for masking (covering and interruption of the defining contours) of objects smaller than a human figure when viewed at close range (_ 10 Meters). This implies a considerable density of clutter patches in colors and sizes consistent with the small scale of virtual battlefield visual features with which they are intended to blend.

Provision of dynamic terrain modeled at resolution sufficient to permit re contouring of the terrain surface to a least-count accuracy of approximately one inch. Passage of personnel and vehicles should leave tracks in the earth when soil type is appropriately soft. These tracks must be capable of being smoothed over by personnel using a virtual rake or branch to redistribute soil. Personnel should be able to dig firing positions using a virtual shovel. Soil removed should mass to form berms with realistic shape and cohesion.

Containers must be modeled that can hold other virtual objects. These involve both open containers that can be emptied by turning them over (e.g., for policing up debris in an LZ) and containers that can be sealed (waterproofing bags) that retain their contents regardless of orientation.

Modeling terrain in such a fashion that multiple horizontal surfaces can be made to exist one above the other permitting objects to pass between them. Thus a fighting position with overhead cover can be constructed that allows a combatant to pass beneath the cover but remain on the surface of the ground. This same extension to the virtual battlefield would permit the individual soldier to seek cover under a bridge span.

Accounting for the dispersion and presence of chemical contaminants that adhere to the ground and to objects that come into contact with it. Changes in the visual appearance of contaminated objects must be supported so that decontamination can be conducted. Presence of chemical contamination in the virtual atmosphere (caused by presence of dispersed aerosol or by dissipation from contaminated objects) must trigger virtual chemical alarm equipment.

Modeling of the interactive physics and structural dynamics of objects arranged to form temporary structures for cover and concealment. Virtual beams, sandbags, metal sheeting, soil, and vegetation should exhibit the appropriate adhesion to one-another, as well as proper structural attributes in response to loads and gravity. Haphazard stacking of structural components should result in a realistic risk of collapse.

Refinement of tactile and kinesthetic display capability to facilitate the manipulation of a wide range of virtual objects ranging from bits of paper and small branches as might be required in clearing an LZ, to two-man lifts of large branches or railroad tie sized beams used in construction of fighting positions with overhead cover. Loads and limits to motion associated with use of tools and lifting of construction materials should be approximated to produce fatigue-induced degradation of human performance.

Means to simulate the effects of fluid drainage and residual wetness must be provided. These effects include specular reflectivity of the wetted surfaces, proper changes to surface friction and temperature/heat capacity characteristics, and believable representation of drainage and pooling of liquids.

New virtual representations of tools and equipment needed to execute the far-term tasks.

Personal equipment: backpack, cooking utensils, web belt, digging tool, etc. All must be separable, and some usable in the execution of activities.

Demolition components, including explosives, wiring, and firing keys. Explosives should be subdividable with explosive effect proportionate to mass employed.

Hoses that can direct streams of liquid decontaminant as pointed by the user. Fluid dynamics (e.g., stream trajectory, splash, runoff, etc.) should be reactive to aiming behavior and believably realistic.

Foliage that can be cut and then utilized as a rake for smoothing over tracks in the soil, or mounded over positions to be camouflaged.

These are all very challenging simulation technology developments demanding not only increased performance along known dimensions of computational technology, but breakthroughs in representational modeling techniques. Fortunately, the simulation objectives sought for the far-term are also being pursued for other purposes, so it is reasonable to be optimistic that within the time available, innovation is likely to produce the desired capability.

ICS Authoring System. The ICS authoring system, if the venue for integrating the new high resolution terrain database, will see its heaviest use in preparation for Block 2 operations. Preparation of the database requires the availability of specialized resources not economically included in the testbed. It is assumed that the database will be sourced to a supporting

organization, either within the Army (such as the Engineering Topographic Laboratory) or outside to a commercial contractor in the database development field. Preparation of the high resolution models of virtual tools and foliage, enhancement of virtual world physics, and the like as required to meet the functional requirements enumerated above, might reasonably be conducted at the ICS Authoring System. If so, a set of software development resources such as computer-aided software engineering tools, high level language compilers, visualization aids, etc. must be provided in the workstation.

ICS System Concept

System Architecture

This study intended to develop the functional requirements for the ICS research facility. The detailed design of the laboratory and its simulation equipment is beyond the scope of the intended effort. Nonetheless, in this section, we present a conceptual architecture responsive to the requirements outlined above, and providing important features that support the evolutionary development of the mature testbed: scaleable architecture; practical modularity; object-oriented structure; largely commercial-off-the-shelf components; and cost-effective hardware and software maintenance.

The ICS system must be configured so that it will accommodate the intended incremental enhancements of the research capability efficiently. As a system evolves, a modular architecture allows the replacement or addition of hardware components and/or software segments without requiring significant redesign. One such architecture, focused on simulation system applications, has been developed and tested under DoD sponsorship. The Modular Simulation (MODSIM)[8] architecture, depicted below in Figure 4 as originally conceived for an aviation application, can be adapted to the ICS.

[8] MODSIM is a generic (initially flight-oriented) set of simulation software functional modules, intended to generalize to all simulation systems, and defined as part of the Air Force's Modular Simulation project.

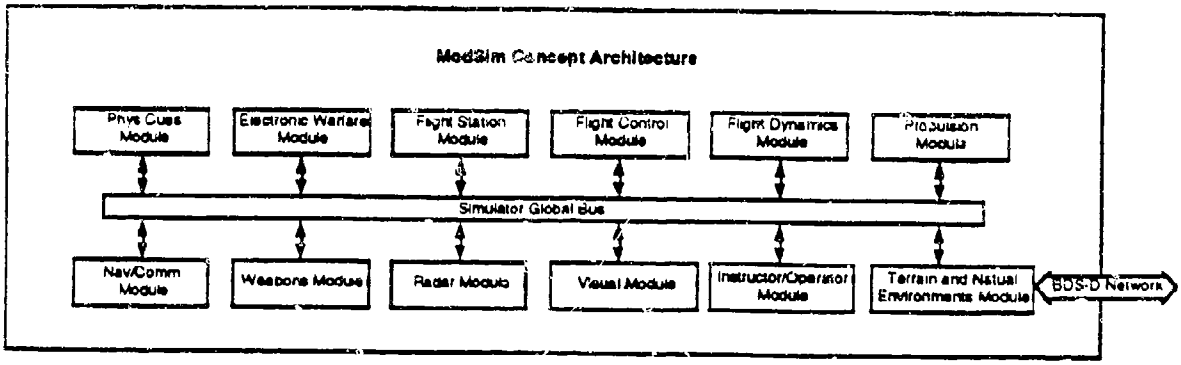

Figure 4. The MODSIM architecture concept as developed for aviation simulation.

When tailored to the ICS requirements presented in the research plan, the MODSIM concept provides the functional schematic shown in Figure 5 for the testbed. The ghosted functions not required in this application. Some others have been retitled to be more appropriate for ICS.

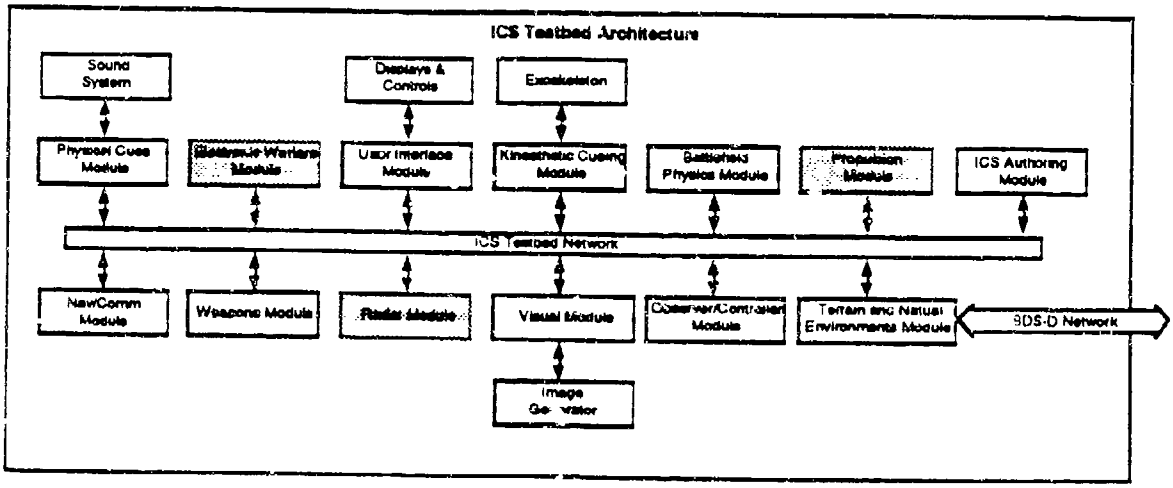

Figure 5. The MODSIM architecture tailored for the ICS testbed.

The functional requirements developed in the Required Operational Capability section suggest that the ICS architectural modules can be partitioned into three physical subsystems: (a) an Observer/Evaluator Workstation; (b) an ICS Authoring Workstation; and (c) the Individual Combat Simulator. Table 26 indicates how the ICS Testbed functional modules are assigned among these three subsystems.

Table 26 Assignment of Functional Modules to ICS Subsystems

Observer/Evaluator Workstation	• Observer /Controller
ICS Authoring Workstation	• ICS Authoring
Individual Combat Simulator	• Physical Cueing • User Interface • Kinesthetic Cueing • Battlefield Physics • Nav/Com • Weapons • Visual • Terrain/Natural Environments

In the following sections, the detailed functionality and evolution of capability of each of these subsystems are discussed. Specific hardware and software recommendations for meeting the requirements are included in Appendix E.

Observer/Evaluator Workstation Subsystem

The Observer/Evaluator Workstation (O/E Workstation) is the focal point for control of testbed operations, and for collection and analysis of data as research is conducted. It combines the functions of the observer/evaluator station, system control station, and the scenario control station developed in the research plan.

O/E Workstation Physical Configuration and Hardware Components. The O/E Workstation will consist of a computing resource, recording capability, and controls and displays including:

A multi-tasking computing resource for testbed and scenario control, and for data capture and analysis. Depending upon the partitioning of functions, simultaneous operations may require that the computer support multi-user operations as well.

Printing capability to produce hard-copy records of raw and processed data, graphics, and imagery (computer generated as well as video still frame). Color printing may be a desirable option.

Recording devices and media to capture digital data from the ICS and BDS-D network, as well as video and audio records of test trials.

Three displays per individual combat simulator (unless one set is timeshared among multiple simulators): (a) one

camera view of the test subject(s) in real space; (b) one perspective view of the virtual combatant from an eye point that can be moved in virtual space during exercises, and in both space and time during replay; and (c) one perspective view of the virtual battlefield from the test subject's point of view.

One or more displays of alpha-numeric data and graphics including separate windows for: (a) measure selection, data collection and replay, and analysis control information; (b) scenario control information; (c) testbed system control information; (d) signal visualization for sound, tactile, and kinesthetic display driving signals; and (e) plan view of the virtual battlefield.

A 3-D sound system that permits evaluators to share in the experience of the test subject either in real-time or during replay.

A two-way audio intercom to each individual combat simulator.

Audio communications between the O/E Workstation, Semi-Automated Forces (SAF) command workstation(s) for any semi-automated forces employed, or other remote interoperating resources. May be telephonic or local intercom depending upon the proximity of the communicating participant.

A 6-DOF controller to position and orient the line of sight of the perspective view eye point.

An ASCII keyboard paired with each alpha-numeric/graphic display.

A mouse type designation device with each alpha-numeric/graphic display.

In addition, the O/E Workstation must provide adequate horizontal desk space for researcher's use in arraying test plans and manual recording of observations.

O/E Workstation Software. The O/E Workstation must be loaded with software to perform the following application level functions:

Control the operation of the testbed, including startup, shutdown, halting and resuming the simulation.

Initializing the virtual battlefield, including selection of active virtual elements in the scenario, positioning these elements, pairing these elements with supporting testbed resources (e.g., individual combat simulators), establishing

their states with respect to consumable supplies, establishing environmental conditions (as they may be controllable), storing these conditions as an aggregated set of scenario initial conditions, and recalling such a set of stored conditions to initialize the testbed.

Controlling the collection of performance data, including selection of data to be collected, starting and halting the recording process, definition of discrete events by specified combination of state conditions, and entry and recording of observer commentary.

Selection of running statistics to be computed during scenario execution, pairing of statistical treatment with performance variables, and formatting of results for graphic display or printing.

Support of interactive post-hoc statistical analyses including selection of method, variables to be examined, computation of statistical outcomes, and formatting of results for graphic display or printing.

Support the generation of displays required for the control and initialization functions.

Provide communications with the testbed internal network and support the exchange of data with other network elements.

Support the user interface for observer/evaluators. Beyond IOC, this may include calculations to interface an HMD-based portal to the virtual battlefield.

Because more than one of these functions may have to be active at a given time, a multi-tasking operating system environment is required. All of the hardware candidates identified above are Unix based and can provide this capability.

ICS Authoring Workstation Subsystem

The ICS authoring workstation is a testbed resource, used primarily off-line, to support the development of databases and models required for execution of the research scenarios. Even if these developments are performed away from the testbed, the availability of the authoring workstation is still essential for software update and maintenance for the entire testbed, and for minor adjustments to databases and models that may be desired on a quick turn-around basis. The ICS authoring station provides the simulation testbed flexibility, maintainability, upgradability, and expandability. The ICS authoring station

design should maximize use of commercial off-the-shelf tools, but utilize an open hardware and software architectural philosophy so that functional extensions can be economically realized.

ICS Authoring Workstation Hardware. The ICS authoring workstation must provide a compatible software host to the other testbed processors so that code can be re-hosted within the testbed easily and with low risk of execution problems. Although there is no requirement for the computational speed to accommodate real-time execution or visualization, as at the other two nodes in the testbed, several considerations dictate in favor of using identical hardware where appropriate at all three locations:

Availability of redundant hardware within the testbed reduces the likelihood of delays in the research program due to breakdowns.

Maintenance and spare parts inventory costs are reduced.

The training burden for operators and technicians is minimized.

In general, the IOC authoring hardware capability should suffice throughout the life of the research program. The requirement to model complex objects at high resolution in the latter stages of the effort might be expedited by the addition of a 3-D laser scanner for automatic development of surface models of real objects.

This subsystem includes the peripherals for authoring, such as a scanner for texture data, a graphics tablet for detail pointing and drawing, and an interface to the ICS network for software porting and to interactively verify simulation data under development. Printed output from the workstation will be required, but developers may consider sharing access to the printer specified for the O/E workstation.

ICS Authoring Workstation Software. The following lists the functional software sub modules/procedures required for the ICS Authoring station. Each item can be provided as a commercial off-the-shelf module with custom extensions.

Database for ICS Simulation Development
Data Libraries
Data Translation
Data Creation and Manipulation
Data Optimization
Data to Objects Descriptions
Logic Libraries
Logic Translation
Logic Creation and Manipulation

Logic Optimization
Code Libraries
Code Translation
Code Creation and Manipulation
Code Optimization, Integration and Debugging
3D Digitizer Object Modeler
On-Line Help

Individual Combat Simulator Subsystem. The individual combat simulator is the heart of the testbed. It generates the reactive virtual environment that is the focal point of the ICS experiments. As indicated in Table 26, the ICS subsystem must provide the hardware and software capable of supporting the following testbed functions:

Physical Cueing
User Interface
Kinesthetic Cueing
Battlefield Physics Computations
Navigation/Communications
Weapons Simulations and Effects Computations
Visual Environment Generation
Terrain/Natural Environments Computations and Network Interface

In addition, the ICS must provide adequate sensory isolation the real world to prevent competing stimuli from interfering with the illusion of the virtual battlefield.

Individual Combat Simulator Hardware Components. The functional requirements identified above can be accommodated by a suite of hardware consisting of four components: (a) cueing displays; (b) response transducers; (c) a host computer; and (d) a computer image generator (which we shall assume may be integrated with the host computer and will be described together). The first of these consists of the suite of information display devices that communicate information about the state of the virtual world and its contents to the senses of the test subject.

The ICS Computer subsystem will be a focus of intensive effort in the course of design of the testbed. The ICS computer configuration must be selected based upon detailed engineering analyses taking into account the structure and complexity of software to be run, the nature of the final testbed architecture, requirements for data exchange with displays and transducers in the ICS, and with the O/E workstation and ICS authoring workstation. Conduct of these analyses is beyond the scope of the present research, hence we make no recommendations with regard to hardware - even for the IOC configuration of the testbed.

Testbed Cost

The cost of establishing and upgrading the ICS testbed is extremely sensitive to the time frame of its development. IOC capabilities described above are essentially off-the-shelf; thus, an estimate to include labor to integrate the testbed systems can be made. Block 1 and Block 2 upgrades are predicated upon technology yet to be developed, that performance trends suggest will be available at appropriate times. The cost expected to procure and integrate these upgrade components is very difficult to project.

Our cost estimate for the IOC Hardware suite is shown in Table 27.

Table 27 Estimated IOC Testbed Hardware Costs

Item	Estimated Cost
O/E Workstation	$116,200
ICS Authoring Station	$48,000
ICS Simulation (2 @ $532,000)	$1,064,000
Hardware Total:	**$1,228,200**

The software compliment of the system consists of some off-the-shelf packages such as, for example, a database development environment and a statistical analysis package, and in addition custom software for scenario control, etc. Under the presumption that the testbed is configured to be DIS-compatible, some software developed under the BDS-D program can be adapted for testbed use and will be assumed to be available free of charge. The balance of the software procurement, development and system integration effort should cost between $2-3 million. Accordingly, inclusive of a reserve for facility preparation, testbed development planning should probably be based on a budget of $3.5 million for procurement, installation, and integration. Note that this does not include support for operations after the research commences.

SUMMARY AND RECOMMENDATIONS

This research has identified 67 ARTEP tasks performed by dismounted combatants that are appropriate for study in a virtual environment. These ARTEP tasks have been further decomposed into 252 activities that are sufficiently specific units of behavior that precise simulation characteristics can be assigned to each one. These activities have been prioritized by the frequency of occurrence within the ARTEP tasks, and have been evaluated as to the time in which the activities can be supported by the technology of virtual environments. Thirty-seven of the 252 activities can be technically supported in the near-term, forty-four activities can be technically supported in the mid-term, and thirteen activities can be technically supported in the far-term

A baseline research plan has been developed that examines the activities in a series of experiments that take advantage of the increasing capabilities of the virtual environment technologies. These initial research experiments will illustrate the technologies that currently support individual combat tasks, and will highlight areas of deficiency, both in terms of technology that must be developed and the tasks that are not yet supportable in virtual environments. Two initial experiments and demonstrations focus on the research issue - "What performance level of the activities can be demonstrated for the various levels of each cueing and response technology in the virtual environment?" A second initial experiment will be undertaken to identify functional relationships between various levels of technology and the performance of the activities in the virtual environment. Two interim experiments and demonstrations will address the research issue - "Does virtual environment technology support training the activities performed by individual dismounted combatants?" A final experiment of the near-term activities will examine any effects on performance and training of the "immersion" characteristic of virtual environments.

The specification for the research testbed presents a functional breakdown of the hardware and software required in an ICS testbed focused on the support of the research plan. In particular, attention has been directed at providing the cueing, response transducing, computational, and image generation capabilities necessary to support the simulation of the IOC, mid-term, and far-term demonstration objectives selected in the earlier task analyses. We have also identified a proposed suite of tools and measures that will support the evaluation of the suitability of the testbed generated environment as an arena for training the selected battlefield activities. Finally, we have specified a set of functional capabilities in hardware and software that can sustain testbed operations through authoring of scenario specific software models and databases.

Although the testbed functionality has been defined to a level that will enable software and hardware engineers to grasp the overall requirements, significant engineering effort is essential in translating the proposed testbed concept into a design. Detailed architectural specifications must be developed by engineering analysis - even for the IOC configuration of the testbed. As a result of this process, requirements for technological breakthroughs that must be realized to enable the creation of the Block 1 and Block 2 upgraded systems can be expected to be identified. These must be promulgated throughout the emergent VR research and development community at the earliest possible time to ensure that efforts are focused in the desired direction, and to maximize the probability of commercial availability of the required capabilities at the appropriate time.

This functional specification should become a living document, so that as changes in the research focus of testbed are desired with the acquisition of new knowledge, as changes in the doctrinal methods of individual combatant mission performance are dictated, and as changes in the projected availability of technology can be predicted, the research plan and testbed conceptual design must be revised in turn. The only way this can be accomplished is by the commitment of the proponent to a sustaining configuration management effort that includes periodic review, validation, and update of the conclusions of this research. The rapid pace of development in the virtual environment technology industry suggests that such a sustaining effort ought to be intensive, ought to be continuous, and ought to be conducted in parallel with and coordinated with the engineering development of the testbed.

REFERENCES

Alluisi, E. A. (1991). The development of technology for collective training: SIMNET, a case history. Human Factors, 33(3), 343-362.

Boff, K. R., Kaufman, K. R., & Thomas, J. P. (1986). Handbook of perception and human performance: Vol. I. Sensory processes and perception. New York: John Wiley & Sons.

Boff, K. R., & Lincoln, J. E. (Eds.). (1988). User's guide - engineering data compendium: Human perception and performance. Ohio: Wright-Patterson Air Force Base.

Carlson, N. R. (1981). Physiology of behavior. Boston: Allyn and Bacon, Inc.

Cochran, W. G., & Cox, G. M. (1957). Experimental designs. New York: John Wiley & Sons.

Department of the Army. (1988). Mission training plan for the tank and mechanized infantry battalion task force (ARTEP 71-2-MTP). Washington, DC.

Department of the Army. (1988). Mission training plan for the tank and mechanized infantry company and company team (ARTEP 71-1-MTP). Washington, DC.

Department of the Army. (1988). Mission training plan for the infantry rifle platoon and squad (ARTEP 7-8-MTP). Washington, DC.

Department of the Army. (1989). Mission training plan for the special forces company: Special reconnaissance (ARTEP 31-807-31-MTP). Washington, DC.

Department of the Army. (1989). Mission training plan for the special forces company: Direct action (ARTEP 31-807-32-MTP). Washington, DC.

Department of the Army. (1990). Battle drills for the infantry rifle platoon and squad (ARTEP 7-8-Drill). Washington, DC.

Gorman, P. F. (1991a). The future of tactical engagement simulation. Proceedings of the 1991 Summer Computer Simulation Conference (pp. 1181-1186). San Diego, CA: The Society for Computer Simulation.

Gorman, P. F. (1991b). SuperTroop via I-Port: Distributed simulation technology for combat development and training development (IDA Paper P-2374). Alexandria, VA: Institute for Defense Analyses.

Hart, R. J., & Sulzen, R. H. (1988). Comparing success rates in simulated combat: Intelligent tactics vs. force. Armed Forces and Society, 14(2), 273-285.

Holding, D. H. (1965). Principles of training. London: Pergamon Press.

Human Factors Society. (1986). Cumulative Index to Human Factors, Third Edition, Volumes 1-27, 1958-1965. Santa Monica: Human Factors Society.

Human Factors Society. (1991). Cumulative Index to Human Factors, 1986-1990 Supplement, Volumes 28-32. Santa Monica: Human Factors Society.

Lampton, D. L., Bliss, J. P., & Gibbons, S. C. (1992, December). Virtual Environment Performance Assessment Battery (Human Subjects Use Plan). Orlando, FL: U.S. Army Research Institute Simulator Systems Research Unit.

Madden, J. L. (1991). Unit training management system, strategy and program for Simulation Networking (SIMNET) (ARI Research Report 1592). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A239 916)

Matlin, M. W. (1983). Perception. Newton, MA: Allyn and Bacon, Inc.

Meister, D. (1985). Behavioral analysis and measurement methods. New York: John Wiley & Sons.

Monday, P. (1992). BDS-D data collection and analysis system (DCAS) (Loral Systems Company Technical Report). Orlando, FL: U.S. Army Simulation, Training, and Instrumental Command (STRICOM).

Morgan, C. T., Cook, J. S., III, Chapanis, A., & Lund, M. W. (Eds.). (1963). Human engineering guide to equipment design. New York: McGraw-Hill Book Company, Inc.

Office of the Assistant Secretary of the Army (Research, Development and Acquisition). (1993, 24 May). Simulation Support to Army Acquisition. Memorandum for the Commanding General, Army Materiel Command and Program Executive Officers.

Osgood, C. E. (1949). The similarity paradox in human learning: A resolution. Psychological Review, 56, 132-143.

Sandra, M. S., & McCormick, E. J. (1987). Human factors in engineering and design (6th ed.). New York: McGraw-Hill Book Company.

Shriver, E. L., Mathers, B. L., Grivin, G. R., Jones, D. R., Word, L. E., Root, R. T., & Hayes, J. F. (1975). REALTRAIN: A new method for tactical training of small units (SP S-4). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Simulation Policy Study. (1990, 18 December). Investment Strategy for Models and Simulation. Memorandum for the Assistant Secretary of Defense, Force Management and Personnel, and the Director of Defense Research and Engineering.

Sulzen, R. H. (1983, May). Winning with tactical engagement simulation. Military Review, pp. 9-19.

VanCott, H. P., & Kinkade, R. G. (Eds.). (1972). Human engineering guide to equipment design. New York: McGraw-Hill Book Company, Inc.

White, S., McMeel, K., & Gross, W. (1990). Unit performance measurement and training program design for networked simulation (PTR-4013-1-90). Woodland Hills, CA: Perceptronics, Inc.

Wickens, C. D. (1984). Engineering psychology and human performance. Glenview, IL: Scott, Foresman and Company.

Word, L. E., & Root, R. T. (1977, June). Tactical Engagement Simulation: Experimental learning. Fort Eustis, VA: U.S. Army Training Support Center.

LIST OF ACRONYMS

AAR	After Action Review
ADCATT	Air Defense Combined Arms Tactical Trainer
AIT	Advanced Individual Training
ARI	Army Research Institute
ARTEP	ARmy Training and Evaluation Program
ATGM	Anti-Tank Guided Missile
AVCATT	AViation Combined Arms Tactical Trainer
BDS-D	Battlefield Distributed Simulation - Developmental
BFIT	Battle Fleet Import Training
CAD/CAM	Computer Aided Design/Computer Aided Manufacturing
CAS	Close Air Support
CCTT	Close Combat Tactical Trainer
CEOI	
CIU	Cell Interface Unit
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DOF	Degree of Freedom
EFFTRAIN	EFFective TRAINing
ENWGS	Enhanced Naval War Game System
FAMSIM	FAMily of SIMulations
FO	Forward Observer
FRAGO	Fragmentary Order
HMD	Helmet-Mounted Display
HRTF	Head-Related Transfer Function
ICS	Individual Combat Simulation(s)
IOC	Initial Operational Capability
LZ	Landing Zone
M&S	Models & Simulations
METL	Mission Essential Task List
METT-T	Mission, Enemy, Terrain and weather, Troops and Time available
MILES	Multiple Integrated Laser System
MODSIM	MODular SIMulation
MTP	Mission Training Plan
MTWAES	Marine Tactical Warfare And Exercise System
MTWS	
O/E	Observer/Evaluator
PDU	Protocol Data Unit
REALTRAIN	REAListic TRAINing
ROC	Required Operational Capability
SAF	Semi-Automated Forces
SCOPES	Squad Combat OPerations Exercise System
SIMNET	SIMulation NETwork
SOF	Special Operations Forces
STRICOM	US Army Simulation, Training and Instrumentation Command
TES	Tactical Engagement Simulation

T&EO . . . . Training and Evaluation Outline
VE . . . . Virtual Environment
VR . . . . Virtual Reality

APPENDIX A VIRTUAL ENVIRONMENT TAXONOMY

1 Behavioral Considerations - Input

1.1 Visual Modality

1.1.1 Image Quality

- 1.1.1.1 Resolution
  - 1.1.1.1.1 Pupillary Aperture Function (Size of Aperture)
  - 1.1.1.1.2 Visual Accommodation
  - 1.1.1.1.3 Static Visual Acuity
  - 1.1.1.1.4 Dynamic Visual Acuity
  - 1.1.1.1.5 Spatial Frequency Resolution (Contrast Sensitivity)
  - 1.1.1.1.6 Central versus Peripheral Field of View
- 1.1.1.2 Luminance/Spectral
  - 1.1.1.2.1 Sensitivity to Light and Contrast
  - 1.1.1.2.2 Color
  - 1.1.1.2.3 Dark Adaptation
  - 1.1.1.2.4 Afterimages
- 1.1.1.3 Flicker And Temporal Change
- 1.1.1.4 Effects of Distortion
  - 1.1.1.4.1 Perceivable Displacements
  - 1.1.1.4.2 Magnification/Reduction
- 1.1.1.5 Eye/Head Movement Dynamics
  - 1.1.1.5.1 Visual Fixation
  - 1.1.1.5.2 Vergence
  - 1.1.1.5.3 Tracking Eye Movements
  - 1.1.1.5.4 Eye/Head Movement Coordination
  - 1.1.1.5.5 Image Stabilization Considerations
  - 1.1.1.5.6 Vestibulo-Ocular Response (Effects of Stabilization/ Vibration)
- 1.1.1.6 Binocular Vision
  - 1.1.1.6.1 Stereo Acuity
  - 1.1.1.6.2 Binocular vs. Monocular Vision
  - 1.1.1.6.3 Geometric Considerations (Vergence Angles)
  - 1.1.1.6.4 Localization

1.1.2 Visual Target Acquisition

- 1.1.2.1 Target Characteristics
  - 1.1.2.1.1 Size (Subtended Angle)
  - 1.1.2.1.2 Spectral Characteristics
  - 1.1.2.1.3 Complexity
  - 1.1.2.1.4 Background Considerations
- 1.1.2.2 Acquisition Mode
  - 1.1.2.2.1 Target Detection
  - 1.1.2.2.2 Target Identification
  - 1.1.2.2.3 Target Recognition
  - 1.1.2.2.4 Target Localization
- 1.1.2.3 Distance Determination

1.1.2.4 Motion Determination
1.1.2.4.1 Motion Detection
1.1.2.4.2 Apparent Motion
1.1.2.4.3 Relative Motion
1.1.2.4.4 Collision Prediction
1.1.2.5 Textual/Numeric Acquisition
1.1.2.5.1 Character Font Size & Spacing

1.2 Auditory Modality

1.2.1 Non-Speech Signals
1.2.1.1 Signal Detectability
1.2.1.2 Masking and Interference
1.2.1.3 Environmental Effects (Ambiance)
1.2.1.4 Localization of Signals
1.2.1.5 Pitch Considerations (Signal Frequency)
1.2.1.6 Loudness (Signal Intensity) Considerations
1.2.1.7 Signal to Noise Relationships
1.2.1.8 Sound Fidelity
1.2.2 Speech Signals
1.2.2.1 Signal Detectability
1.2.2.2 Masking and Interference
1.2.2.3 Environmental Effects (Ambiance)
1.2.2.4 Localization of Signals
1.2.2.5 Pitch Considerations (Signal Frequency)
1.2.2.6 Loudness (Signal Intensity) Considerations
1.2.2.7 Signal to Noise Relationships
1.2.2.8 Sound Fidelity
1.2.3 Acoustic Target Acquisition
1.2.3.1 Target Characteristics
1.2.3.2 Acquisition Mode
1.2.3.2.1 Target Detection
1.2.3.2.2 Target Identification
1.2.3.2.3 Target Recognition
1.2.3.2.4 Target Localization
1.2.3.3 Localization

1.3 Vestibular Modality

1.3.1 Angular Acceleration
1.3.2 Linear Acceleration
1.3.3 Body Rotation
1.3.4 Adaptation
1.3.5 Vibration

1.4 Propricception

1.4.1 Gross Motor Movement
1.4.2 Fine Motor Movement

1.5 Cutaneous (Tactile) Modality
1.5.1 Cutaneous Sensitivity
1.5.2 Pattern Discrimination
1.5.3 Thermal Sensitivity
1.5.4 Force Feedback Considerations

1.6 Olfactory Modality

1.6.1 Sensitivity (Detection)
1.6.2 Location/Orientation Discrimination

2 Behavioral Considerations - Output

2.1 Speech

2.1.1 Continuous/Discrete
2.1.2 Vocabulary Size
2.1.3 Speaker Dependence
2.1.4 Background Noise Sensitivity

2.2 Position and Orientation

2.2.1 Psychomotor Movement
- 2.2.1.1 Hand Movement
- 2.2.1.2 Finger Movement
- 2.2.1.3 Head Movement
- 2.2.1.4 Body Movement

3 Technology Approaches

3.1 Interactive Displays

3.1.1 Visual Display
- 3.1.1.1 Inclusive Virtual Visual Display
- 3.1.1.2 See-Through Virtual Display
  - 3.1.1.2.1 Use With Real Background
  - 3.1.1.2.2 Use With Projected Background
- 3.1.1.3 Personal Projected Display
- 3.1.1.4 Theater Projected Display (Theater)

3.1.2 Acoustic Display
3.1.2.1 3D Sound Generator With Stereo Headset (Occluded)
3.1.2.2 3D Sound Generator With Stereo Headset (Non-Occluding)
3.1.2.3 Multiple Speaker Based System
3.1.3 Tactile Display
3.1.3.1 Pneumatic Bladders
3.1.3.2 Vibrotactile
3.1.3.3 Electroshock
3.1.3.4 Temperature
3.1.4 Force Feedback Display
3.1.4.1 Viscosity Modulation Materials
3.1.4.2 Pneumatic Bladders
3.1.4.3 Exoskeleton
3.1.5 Olfactory Display
3.1.5.1 Scratch & Sniff
3.1.5.2 Vials
3.1.5.3 Synthesis
3.1.6 Kinesthetic/Proprioceptive Display

3.2 Behavioral Effectors (Physical or Virtual Objects That Simulate Objects Used In Tasks)

3.2.1 Psychomotor Movement Sensing
3.2.1.1 Hand Movement
3.2.1.2 Finger Movement
3.2.1.3 Head Movement
3.2.1.4 Body Movement
3.2.2 Instrumented Objects (E.G. Rifle, Grenade, Knife)

4 Technology Considerations (Linked to Technology Approach)

4.1 Interactive Display Factors

4.1.1 Factors Affecting the Ability to See the Display
4.1.1.1 Spatial Factors
4.1.1.1.1 Instantaneous Field-of-View
4.1.1.1.2 Field of Regard
4.1.1.1.3 Subtended Visual Angle of Resolution Element
4.1.1.1.4 # of Resolution Elements
4.1.1.1.5 Modulation Transfer Function
4.1.1.1.6 Static Model Complexity
4.1.1.1.7 Dynamic Model Complexity
4.1.1.1.8 Image Realism
4.1.1.1.9 Image Detail (# of Objects)
4.1.1.1.10 Depth Cues
4.1.1.1.11 Stereographic
4.1.1.1.12 Accommodative
4.1.1.1.13 Secondary Depth Cues

4.1.1.2 Luminance/Spectral Factors
  4.1.1.2.1 Luminance
  4.1.1.2.2 Color Rendition
  4.1.1.2.3 Contrast Without See-Thru
  4.1.1.2.4 Contrast With See-Thru
4.1.1.3 Temporal Factors
  4.1.1.3.1 Update Rate
  4.1.1.3.2 Through-Put Delays
  4.1.1.3.3 Refresh Rate
  4.1.1.3.4 Persistence/Duty Cycle
4.1.1.4 Image Stabilization Factors
  4.1.1.4.1 Precision
  4.1.1.4.2 Accuracy
  4.1.1.4.3 Scale Factor
  4.1.1.4.4 Boresighting
  4.1.1.4.5 Motion Volume

4.1.2 Factors Affecting the Ability to See the Outside World
  4.1.2.1 Transmittance of Combiner
  4.1.2.2 Obscuration By Display Image
  4.1.2.3 Luminance of Outside World
  4.1.2.4 Contrast of Outside World

4.2 Interactive Auditory Display Factors

4.2.1 Factors Affecting the Ability to Hear A Sound
  4.2.1.1 Spatial Factors
    4.2.1.1.1 Asimuthal Resolution
    4.2.1.1.2 Altitudinal Resolution
    4.2.1.1.3 Depth Resolution
    4.2.1.1.4 Complexity of Room/Environment
    4.2.1.1.5 Number of Separately Spatialized Objects
    4.2.1.1.6 Doppler Fidelity
  4.2.1.2 Intensity/Spectral Factors
    4.2.1.2.1 Dynamic Range
    4.2.1.2.2 Intensity Resolution
    4.2.1.2.3 Spectral Resolution
  4.2.1.3 Temporal Factors
    4.2.1.3.1 Update Rate
    4.2.1.3.2 Refresh Rate
    4.2.1.3.3 Through-Put Delays
    4.2.1.3.4 Persistence
  4.2.1.4 Sound Field Stabilization Factors
    4.2.1.4.1 Precision
    4.2.1.4.2 Accuracy
    4.2.1.4.3 Boresighting
    4.2.1.4.4 Scale Factor
    4.2.1.4.5 Motion Volume

4.2.2 Factors Affecting the Ability to Hear the Outside World
  4.2.2.1 Transmittance of Combiner
  4.2.2.2 Interference of Displayed Sounds
  4.2.2.3 Intensity of Outside Sounds

4.3 Interactive Tactile Display Factors

4.3.1 Factors Affecting the Ability to Feel A Display
- 4.3.1.1 Spatial Density of Stimulus Elements
- 4.3.1.2 Range of Stimulus Factors
  - 4.3.1.2.1 Pressure Range
  - 4.3.1.2.2 Temperature Range
  - 4.3.1.2.3 Pain Resolution
- 4.3.1.3 Resolution of Stimulus Factors
  - 4.3.1.3.1 Pressure Resolution
  - 4.3.1.3.2 Temperature Resolution
  - 4.3.1.3.3 Pain Resolution
- 4.3.1.4 Temporal Factors
  - 4.3.1.4.1 Update Rate
  - 4.3.1.4.2 Refresh Rate
  - 4.3.1.4.3 Through-Put Delays
- 4.3.1.5 Persistence
- 4.3.1.6 Surface Stabilization Factors
  - 4.3.1.6.1 Precision
  - 4.3.1.6.2 Accuracy
  - 4.3.1.6.3 Boresighting
  - 4.3.1.6.4 Scale Factor
  - 4.3.1.6.5 Motion Volume

4.3.2 Factors Affecting the Ability to Feel the Outside World
- 4.3.2.1 Transmittance of Tactile Display
- 4.3.2.2 Interference of Virtual Tactile Stimuli
- 4.3.2.3 Intensity of Real Tactile Stimuli

4.4 Interactive Force Feedback Display Factors

4.4.1 Spatial Factors
- 4.4.1.1 Density of Resistance Elements
- 4.4.1.2 Degrees of Freedom

4.4.2 Resistance Generation
- 4.4.2.1 Range of Force
- 4.4.2.2 Resolution of Force
- 4.4.2.3 Range of Torque
- 4.4.2.4 Resolution of Torque

4.4.3 Temporal Factors
- 4.4.3.1 Update Rate
- 4.4.3.2 Refresh Rate
- 4.4.3.3 Through-Put Delays
- 4.4.3.4 Persistence

4.4.4 Tactile Model Stabilization Factors
- 4.4.4.1 Precision
- 4.4.4.2 Accuracy
- 4.4.4.3 Boresighting
- 4.4.4.4 Scale Factor
- 4.4.4.5 Motion Volume

4.5 Interactive Olfactory Display Factors

4.5.1 Factors Affecting the Ability to Acquire Olfactory Information
- 4.5.1.1 Stimulus Factors
  - 4.5.1.1.1 Number of Distinct Stimuli
  - 4.5.1.1.2 Stimulus Intensity Range
  - 4.5.1.1.3 Stimulus Intensity Resolution
- 4.5.1.2 Temporal Factors
  - 4.5.1.2.1 Update Rate
  - 4.5.1.2.2 Refresh Rate
  - 4.5.1.2.3 Through-Put Delays
  - 4.5.1.2.4 Persistence
- 4.5.1.3 Olfactory Field Stabilization Factors
  - 4.5.1.3.1 Precision
  - 4.5.1.3.2 Accuracy
  - 4.5.1.3.3 Scale Factor
  - 4.5.1.3.4 Motion Volume

4.5.2 Factors Affecting the Ability to Smell the Outside World
- 4.5.2.1 Transmittance of Combiner
- 4.5.2.2 Interference of Displayed Scents

4.5.3 Intensity of Outside Scents

4.6 Multiple Modality Display Factors

4.6.1 Intermodal Interference

4.6.2 Intermodal Synergy

4.6.3 Intermodal Correlation

4.6.4 Interstimulus Temporal Factors (E.G. Delays Between Presentation to Different Sensory End-Organs)

4.6.5 Interstimulus Spatial Factors

4.7 Artifacts

4.7.1 Effects of Encumbrances
- 4.7.1.1 Limited Motion Box
- 4.7.1.2 Attachments (E.G. Wires)
- 4.7.1.3 Weight/Size/Form Factor/Center of Gravity of Headgear

4.8 Behavior Transducer Factors

APPENDIX B HUMAN PERFORMANCE BIBLIOGRAPHY

Taxonomy Category		References
1	Behavioral Considerations-Input	Wickens, C.D., S.J. Mountford, & Shreiner, W. (1981). Multiple resources, task hemispheric integrity and individual differences in time sharing. *Human Factors, 23*(2), 211-229.
1.1	Visual Modality	Haber, R. (1970). How we remember what we see. *Scientific America, 222*, 104-112.
1.1.1	Image Quality	
1.1.1.1	Resolution	Yamaguchi, H., Tomono, A., & Kobayashi, Y. (1989, November 8). Proposal for a large visual field display employing eye movement tracking. *Proceedings of the SPIE - The International Society for Optical Engineering Optics, Illumination and Image Sensing for Machine Vision IV, 1194.* Philadelphia, PA, USA.
1.1.1.1.1	Pupillary Aperture Function	Boff, K. R. and Lincoln, J. E. (Eds.) (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.105; 1.106; 1.203; 1.209; 1.614; 1.638)
		Kaufman. K.R., & Thomas, J.P. (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Leibowitz, H. (1952). The effect of pupil size on visual acuity for photometrically equated test fields at various levels of luminance. *Journal of the Optical Society of America, 42*, 416-422.
1.1.1.1.2	Visual Accommodation	Boff, K. R. and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.222; 1.223; 1.238; 1.224; 1.226; 1.228; 1.237)
		Campbell, F.W., Westheimer, G. & Robson, J.G. (1958). Significance of fluctuations of accommodation. *Journal of the Optical Society of America, 43*, 669.
1.1.1.1.3	Static Visual Acuity	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.201; 1.203; 1.212; 1.305; 1.602; 1.603; 1.606; 1.608; 1.613)
		Johnson, C.A., (1976). Effects of luminance and stimulus distance on accommodation and visual resolution. *Journal of the Optical Society of America, 66*, 138-142.

Taxonomy Category		References
		Shlaer, S. (1937). The relation between visual acuity and illumination. *Journal of General Physiology, 21*, 165-188.
		Kling, J., & Riggs, .. (Eds.) (1971). *Woodworth & Schlosberg's experimental psychology* (pp. 300-306). New York: Holt, Rinehart and Winston.
1.1.1.1.4	Dynamic Visual Acuity	Bartlett, N., Brown, J., Hsia, Y., & Mueller, C. (1965). In C. Graham (Ed.) *Vision and visual perception*. New York: Wiley.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.617; 1.619; 1.621; 1.622; 5.203,4,9; 11.105,6)
		Brown, J. (1931). The thresholds for visual movement. *Psychologische Forschung, 14*, 249-268.
		Brown, R., & Conklin, J. (1954). The lower threshold of visible movement as a function of exposure time. *The American Journal of Psychology, 67*, 104-110.
		Brown, R. (1957). The effect of extent on the intensity-time relation for the visual discrimination of movement. *Journal of Comparative and Physiological Psychology, 50*, 109-114.
		Campbell, F.W., & Maffei, L. (1981). The influence of spatial frequency and contrast on the perception of moving patterns. *Vision Research, 21*, 713-721.
		Elkin, E.H., (1962). Target velocity, exposure time and anticipatory tracking time as determinants of dynamic visual acuity (DVA). *Journal of Engineering Psychology, 1*, 26-33.
		Ludvigh, E., & Miller, J.W. (1958). Study of visual acuity during the ocular pursuit of moving test objects. I. Introduction. *Journal of the Optical Society of America, 48*, 799-802.
		Miller. J.W. (1958). Study of visual acuity during the ocular pursuit of moving test objects. II. Effects of direction of movement, relative movement, and illumination. *Journal of the Optical Society of America, 48*, 803-808.
		Miller, J. & Ludvigh, E., (1961). The perception of movement persistence in the Ganzfield. *Journal of the Optical Society of America, 51*, 57-60.

Taxonomy Category		References
		Miller, J.W., & Ludvigh, E. (1962). The effects of relative motion on visual acuity. *Survey of Ophthalmology, 7*, 83-116.
		Shaffer, O., & Wallach, H. (1966). Extent of motion thresholds under subject-relative and object-relative conditions. *Perception & Psychophysics, I*, 447-451.
1.1.1.1.5	Spatial Frequency Resolution	Appelle, S. (1972). Perception and discrimination as a function of stimulus orientation: The "oblique effect" in man and animals. *Psychological Bulletin, 78*, 266-278.
		Barlow, H.B., (1958). Temporal and spacial summation in human vision at different background intensities. *Journal of Physiology, 141*, 337-350.
		Bartlett, N.R. (1965). Thresholds as dependent on some energy relations and characteristics of the subject. In C.H. Graham (Ed.), Vision and visual perception (pp. 154-184). New York: Wiley.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.628; 1.629; 1.649; 1.652)
		Graham, C.H. (1965). Perception of movement. In C.H. Graham (Ed.), Vision and visual perception (pp. 575-588). New York: Wiley.
1.1.1.1.6	Central Vs. Peripheral Field Of View	Arakawa, Y. (1953). Quantitative measurements of visual field for colors. *American Journal of Ophthalmology, 36*, 1594-1601.
		Bartlett, N., Brown, J., Hsia, Y., & Mueller, C. (1965). In C. Graham (Ed.) *Vision and visual perception*. New York: Wiley.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.201; 1.202; 1.235; 1.237; 1.632,3,7; 5.203,4,5; 8.116; 11.204; 11.409)
		Campbell, F.W., & Maffei, L. (1981). The influence of spatial frequency and contrast on the perception of moving patterns. *Vision Research, 21*, 713-721.
		Rogers, J.G. (1972). Peripheral contrast thresholds for moving images. *Human Factors, 14*, 199-205.

Taxonomy Category		References
1.1.1.2	Luminance/ Spectral	
1.1.1.2.1	Sensitivity To Light And Contrast	Beebe-Center, J. G., Carmichael, L., & Mead, L. C. (1944). Daylight training of pilots for night flying. *Aeronautical Engineering Review, 3*, 9-29. Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.013; 1.101; 1.109; 1.110; 1.302; 1.305; 1.308; 1.403,4; 1.502; 1.601; 1.646; 1.705; 1.720; 5.1001; 11.103; 11.221) Hood, D., & Finkelstein, M. (1986). Sensitivity to light. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol I. Sensory processes and perception.* New York: Wiley. Kaiser, P.K., Herzberg, P.A., & Boynton, R.M. (1971). Chromatic border distinctness and its relation to saturation. *Vision Research, 11*, 953-968. Stiles, W.S., & Crawford, B.H. (1937). The effect of a glaring light source on extrafoveal vision. *Proceedings of the Royal Society of London, B122*, 255-280.
1.1.1.2.2	Color	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.101; 1.107; 1.110; 1.237; 1.304; 1.702,3,4,5; 5.1001; 11.126) Boynton, R.M. (1979). *Human color vision,* New York: Holt, Rinehart, and Winston. Burnham, R.W., Hanes, R.M., & Bartelson, C.J. (1963). *Color: A guide to basic facts and concepts.* New York: Wiley. MacAdam, D.L. (1942). Visual sensitivities to color differences in daylight. *Journal of the Optical Society of America, 32*, 247-274. Munsell, A.H. (1942). *Book of color.* Baltimore: Munsell Color Book Co. Siegel, M.H. (1965). Color discrimination as a function of exposure time. *Journal of the Optical Society of America, 55*, 566-58. Wright. W.D. (1941). The sensitivity of the eye to small color differences. *Proceedings of the Physical Society* (London), *53*, 93-112.

Taxonomy Category		References
		Wyszecki, G. M., & Stiles, W. S. (1982). *Color Science* (2nd ed.). New York: Wiley.
1.1.1.2.3	Dark Adaptation	Arden, G.B., & Weale, R.A. (1954). Nervous mechanisms and dark adaptation. *Journal of Physiology, 125*, 417-426.
		Beebe-Center, J.G., Carmichael, L., & Mead, L.C. (1944). Daylight training of pilots for night flying. *Aeronautical Engineering Review, 3*, 9-29.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.406-11)
		Brown, J.L., Graham, C.H., Leibowitz, H., & Ranken, H.B. (1953). Luminance thresholds for the resolution of visual detail during dark adaptation. *Journal of the Optical Society of America, 43*, 1907-202.
		Crawford, B.H. (1937). The change of visual sensitivity with time. *Proceedings of the Royal Society, 129B*, 94-106.
		Hecht, S., Haig, C., & Wald, G. (1935). The dark adaptation of retinal fields of different size and location. *Journal of General Physiology, 19*, 321-337.
		Hood, D.C., & Finkelstin, M.A. (1986). Sensitivity to light. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. New York: Wiley.
		Montellese, S., Brown, J.L., & Sharpe. L.T. (1979). Changes in critical during dark adaptation. *Vision Research, 10*, 1147-1153.
1.1.1.2.4	Afterimages	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.309)
		Brown, J.L. (1965). Afterimages. In C.H. Graham (Ed.), *Vision and visual perception* (pp. 479-503) New York: Wiley.
		Padgham, C.A. (1968). Measurements of the color sequences in positive visual afterimages. *Vision Research, 8*, 939-949.
		Stromeyer, C.F., III. (1972). Edge-contingent color aftereffects: Spatial frequency specificity. *Vision Research, 12*, 717-733.

Taxonomy Category		References
1.1.1.3	Flicker And Temporal Change	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.5; 11.122)
		Brown, J.L. (1965). Flicker and intermittent stimulation. In C.H. Graham (Ed.), *Vision and visual perception.* New York: Wiley.
		de Lange, H. (1954). Relationship between critical flicker frequency and a set of low frequency characteristics of the eye. *Journal of the Optical Society of America, 44,* 380-389.
		de Lange, H. (1958). Research into the dynamic nature of the human fovea-cortex systems with intermittent and modulated light. *Journal of the Optical Society of America, 44,* 777-789.
		Kelly, D.H. (1959). Effects of sharp edges in a flickering field. *Journal of the Optical Society of America, 49,* 730-732.
		Lythgoe, R.J., & Tansley, K. (1929). The relation of the critical frequency of flicker to the adaptation of the eye. *Proceedings of the Royal Society (London), B105,* 60-92.
		Mandler, M.B. (1984). Temporal frequency discrimination above threshold. *Vision Research, 12,* 1873-1880.
		Roehrig, W.C. (1959). The influence of area on the critical flicker-fusion threshold. *Journal of Psychology, 47,* 317-330.
		Roehrig, W.C. (1959). The influence of the portion of the retina stimulated on the critical flicker-fusion threshold. *Journal of Psychology, 48,* 57-63.
		White, K.D., & Baker, H,D. (1976). Foveal CFF during the course of dark adaptation. *Journal of the Optical Society of America, 66,* 70-72.
1.1.1.4	Effects Of Distortion	
1.1.1.4.1	Perceivable Displacements	Abplanaip, P., & Held R. (1965, April). *Effects of de-correlated visual feedback on adaptation to wedge prisms.* Paper presented at the meeting of the Eastern Psychological Association. Atlantic City, NJ.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.950; 5.1101,3,4)

Taxonomy Category		References
		Cohen, M.M., & Held, R. (1960, April). *Degrading visual-motor coordination by exposure to disordered re-afferent stimulation.* Paper presented at the meeting of the Eastern Psychological Association, New York, NY.
		Efstathiou, A. (1963, April). *Correlated and de-correlated visual feedback in modifying eye-hand coordination.* Paper presented at the meeting of the Eastern Psychological Association, New York, NY.
		Howard, I.P. (1968). Displacing the optical array. In S.J. Freedman (Ed.), *The neuropsychology of spatially-oriented behavior.* Homewood, IL: Dorsey Press.
		Uhlarik, J.J. (1973). Role of cognitive factors on adaptation to prismatic displacement. *Journal of Experimental Psychology, 98*, 223-232.
		Welch, R.B. (1978). *Perceptual modification: Adapting to altered sensory environments.* New York: Academic Press.
1.1.1.4.2	Magnification Minification	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 5.907; 5.909)
1.1.1.5	Eye/Head Movement Dynamics	
1.1.1.5.1	Visual Fixation	Baker, C. (1962). *Man and radar displays.* New York: Pergamon Press.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.913,5; 7.015; 7.505)
		Fisher, D., Monty, R., & Senders, J. (1981). *Eye movements: Cognition and visual perception.* Hillsdale, NJ: Erlbaum.
		White, C., & Ford, A. (1960). Eye movement during simulated radar search. *Journal of the Optical Society of America, 50*, 909-913.
1.1.1.5.2	Vergence	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.808; 1.905; 1.950,2,4)
		Duwaer, A.L., & van der Brink, G. (1981). Diplopia thresholds and the initiation of vergence eye-movements. *Vision Research, 21*, 1727-1737.

Taxonomy Category		References
		Frisby, J., & Mayhew, J. (1980). The role of spatial frequency tuned channels in vergence control. *Vision Research, 20*, 727-732.
		Jones, R., & Kerr, K.E. (1972). Vergence eye movements to pairs of disparity stimuli with shape selection cues. *Vision Research, 12*, 1425-1430.
		Mitchell, D.E. (1970). Properties of stimuli eliciting vergence eye movements and stereopsis. *Vision Research, 10*, 145-162.
		Westheimer, G., & Mitchell, D.E. (1969). The sensory stimulus for disjunctive eye movements. *Vision Research, 9*, 749-755.
1.1.1.5.3	Tracking Eye Movements	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.904,6; 1.915; 1.945,7; 5,202)
		Collewijn, H., vander Mark, F., & Jansen, T.C. (1975). Precise recording of human eye movement. *Vision Research, 15*, 447-450.
		Cornsweet, N., & Crane, H.D. (1973). An accurate eye tracker using first and fourth Purkinje image. *Journal of the Optical Society of America, 63*, 921-928.
		Eizenman, M., Frecker, R.C., & Hallett, P.E. (1984). Precise noncontacting measurement using the corneal reflex. *Vision Research, 24*, 167-174.
		Hallett, PE. (1986). Eye movements. In K.R. Boff, L. kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Ho[illegible]man, J.D., Sedgwick, H.A. & Festinger, L. ([illegible]78). Interaction of perceptual monitored and [illegible]onitored efferent commands for smooth pursuit [illegible]vements. *Vision Research, 18*, 1545-1555.
		[illegible] A., Fendrich, R., & Pleune, J. (1979). [illegible]th pursuit eye movements: Is perceived [illegible]n necessary? *Science, 203*, 1361-1363.
		Young, L.R., & Sheena, W.S. (1975). Survey of eye movement recording methods. *Behavior Research Methods and Instrumentation, 7*, 397-429.

Taxonomy	Category	References
1.1.1.5.4	Eye/Head Movement Coordination	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.913; 1.928; 1.960; 1.958; 5.1120; 10.418) Mack, A., Fendrich, R., & Pleune, J. (1978). Adaptation to an altered relation between retinal image displacements and saccadic eye movements. *Vision Research, 18*, 1321-1327. Wallach, H., & Flaherty, E.W. (1976). Rapid adaptation to a prismatic distortion. *Perception & Psychophysics, 19*, 261-266. Wallach, H., & Floor, L. (1970). On the relation of adaptation to field displacement during head movements to the constancy of visual direction. *Perception & Psychophysics, 8*, 95-98. Wallach, H., & Frey, K.J. (1969). Adaptation in the constancy of visual direction measured by a one-trial method. *Perception & Psychophysics, 5*, 249-252. Wallach, H., & Frey, K.J. (1972). Difference in the dissipation of the effect of adaptation to two kinds of field displacement during head movements. *Perception & Psychophysics, 11*, 31-34. Wallach, H., Frey, K.J., & Romney, G. (1969). Adaptation to field displacement during head movement unrelated to the constancy of visual direction. *Perception & Psychophysics, 5*, 253-256.
1.1.1.5.5	Image Stabilization Considerations	
1.1.1.5.6	Vestibuo-Ocular Response (Effects Of Stabilization/ Vibration)	Barr, C.C., Schultheis, L.W., & Robinson, D.A. (1976). Voluntary, non-visual control of human vestibulo-ocula reflex. *Acta Otolaryngologica, 81*, 365-375. Boff, Kenneth R. and Lincoln, Janet E. (ed.) *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio: 1988. (Section 1.917,8; 1.922; 10.406,7,9; 10.417) Griffin, M.J. (1976). Eye motion during whole-body vertical vibration. *Human Factors, 18*, 601-606.

Taxonomy Category		References
		Jurgens, R., Becker, W., & Rieger, P). (1981). Different effects involved in the interaction of saccades and the vestibulo-ocular reflex. *Annals of the New York Academy of Sciences, 374,* 744-754.
		Pulaski, P.D., Zee, D.S., & Robinson, D.A. (1981). The behavior of the vestibulo-ocular reflex at high velocities of head rotation. *Brain Research, 222,* 159-165.
1.1.1.6	Binocular Vision	Ellis, S.R., Tharp, G.K., Grunwald, A.J., & Smith, S. (1991). Exocentric judgements in real environments and stereoscopic displays. *Proceedings of the Human Factors Society 35th Annual Meeting (2),* 1442-1446. Santa Monica, CA, USA: Human Factors Society, Inc.
		Laglands, H.M.S. (1926). Experiments in binocular vision. *Transactions of the Optical Society (London), 28,* 45-82.
		Ogle, K.N. (1950). *Researches in binocular vision.* Philadelphia: Saunders.
		Ogle, K.N. (1962) Spatial localization through binocular vision. In H. Davson (Ed.), *The eye: Vol. 4* (pp. 271-324). New York: Academic Press.
1.1.1.6.1	Stereo Acuity	Berry, R.N. (1948). Quantitative relations among vernier, real depth, and stereoscopic depth acuities. *Journal of Experimental Psychology, 38,* 708-721.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 5.905; 5.922; 5.917)
		Butler, T.W., & Westheimer, G. (1978). Interference with stereoscopic acuity: Spatial, temporal, and disparity tuning. *Vision Research, 18,* 1387-1392.
		Ogle, K.N. (1956). Stereoscopic acuity and the role of convergence. *Journal of the Optical Society of America, 46,* 269-273.
		Ogle, K.N. (1963). Stereoscopic depth perception and exposure delay between images to the two eyes. *Journal of the Optical Society of America, 53,* 1296-1304.
		Westheimer, G. (1979). Cooperative neural processes involved in stereoscopic acuity. *Experimental Brain Research, 36,* 585-597.

Taxonomy Category		References
1.1.1.6.2	Binocular Vs. Monocular Vision	Arditi, A., Anderson, P., & Movshon, J.A. (1981). Monocular and binocular detection of moving sinusoidal gratings, *Vision Research 21*, 329-336.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.225; 1.232; 1.801,2; 5.909)
		Campbill, F.W., & Green, D.G. (1965). Monocular versus binocular visual acuity. *Nature, 208*, 191-192.
		Reeves, P. (1918). Rate of pupillary dilation and contraction. *Psychological Review, 25*, 330-340.
1.1.1.6.3	Geometric Considerations (Vergence Angles)	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.208,9; 1.808; 1.956; 5.905)
		Duwaer, A.L., & van der Brink, G. (1981). Diplopia thresholds and the initiation of vergence eye-movements. *Vision Research, 21*, 1727-1737.
		Frisby, J., & Mayhew, J. (1980). The role of spatial frequency tuned channels in vergence control. *Vision Research, 20*, 727-732.
		Jones, R., & Kerr, K.E. (1972). Vergence eye movements to pairs of disparity stimuli with shape selection cues. *Vision Research, 12*, 1425-1430.
		Mitchell, D.E. (1970). Properties of stimuli eliciting vergence eye movements and stereopsis. *Vision Research, 10*, 145-162.
1.1.1.6.4	Localization	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.813; 5.906; 5.911)
		Ogle, K.N. (1962) Spatial localization through binocular vision. In H. Davson (Ed.), *The eye: Vol. 4* (pp. 271-324). New York: Academic Press.
1.1.2	Visual Target Acquisition	Brainard, R.W., & Marshall, R.H. (1965, January). *Resolution requirements for identification of targets in television imagery* (NA-63H-794). Columbus, OH: North American Aviation. (DTIC No. AD744902)

Taxonomy Category		References
		Craig, G.L. (1975, April). *Vehicle detection on television: A laboratory experiment* (NWC-TP-5636). China Lake, CA: Naval Weapons Center. (DTIC No. AD9199898)
		Erickson, R.A. (1978). Line criteria in target acquisition with television. *Human Factors, 20*, 573-588.
		Jones, D.B. (1973, March). *A collection of unclassified technical papers on target acquisition*. Vol. I. (OA-6201-Vol-I). Orlando, FL: Martin Marietta Aerospace. (DTIC No. AD758022)
		Silbernagel, B.L. (1982). Using realistic sensor, target, and scene characteristics to develop a target acquisition model. *Human Factors, 24*, 321-328.
1.1.2.1	Target Characteristics	Boman, D., Gille, J., Piantanida, T., & Larimer, J. (1992). Effects of visual-field size and distracter attributes on target detection in virtual-reality systems. *Investigative Ophthalmology & Visual Science, 33*(4), 1416.
1.1.2.1.1	Size (Subtended Angle)	Akerman, A., III & Kinzly, R.E. (1979). Predicting aircraft detectability. *Human Factors, 21*, 277-291.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.934; 5.105; 7.526; 7.602,3,5-8,10; 7.614; 11.104; 11.114)
		Blackwell, H.R. (1946). Contrast thresholds of the human eye. *Journal of the Optical Society of America, 36*, 624-643.
		Duntley, S.Q. (1948). The visibility of distant objects. *Journal of the Optical Society of America, 38*, 237-249.
		Krendel, E.S., & Wodinsky, J. (1960). Visual search in unstructured fields. In A. Morris and E.P. Horne (Eds.) *Visual search techniques* (Publication 712, pp. 151-169). Washington, DC: National Academy of Sciences, National Research Council
		Lamar, E.S., Hecht, S., Shlaer, S., & Hendley, C.D. (1947). Size, shape, and contrast in detection of targets by daylight vision. I Data and analytical description. *Journal of the Optical Society of America, 37*, 531-545.

Taxonomy Category		References
		Short, E.A. (1961). *Visual detection of aircraft in mid-air collision situations* (Master's Thesis). Monterey, CA: United States Naval Postgraduate School. (DTIC No. AD480757)
		Taylor, J.H. (1961). *Contrast thresholds as a function of retinal position and target size for the light adapted eye* (Visibility Laboratory Rep. 61-10). La Jolla, CA: Scripps Institute of Oceanography.
1.1.2.1.2	Spectral Characteristics	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 7.608; 7.614)
		Erickson, R.A. (1978). Line criteria in target acquisition with television. *Human Factors, 20,* 573-588.
		Silbernagel, B.L. (1982). Using realistic sensor target and scene characteristics to develop a target acquisition model. *Human Factors, 24,* 321-328.
1.1.2.1.3	Complexity	Attneave, F. (1955). Symmetry, information and memory for patterns. *American Journal of Psychology, 68,* 209-222.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 7.608; 7.614)
		Deese, J. (1956). *Complexity of contour in the recognition of visual form* (WADC-TR-56-60). Wright-Patterson Air Force Base, OH: Wright Aeronautical Development Center. (DTIC No. AD094610)
		Erickson, R.A. (1978). Line criteria in target acquisition with television. *Human Factors, 20,* 573-588.
		Garner, W.R. (1962). *Uncertainty and structure as psychological concepts.* New York: Wiley.
		Garner, W.R. & Sutcliff, D. (1974). The effects of goodness on encoding time. *Perception & Psychophysics, 16,* 426-430.
		Silbernagel, B.L. (1982). Using realistic sensor target and scene characteristics to develop a target acquisition model. *Human Factors, 24,* 321-328.
1.1.2.1.4	Background Considerations	Blackwell, H.R. (1946). Contrast thresholds of the human eye. *Journal of the Optical Society of America, 36,* 624-643.

Taxonomy Category		References
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 6.307,8; 7.517; 7.602,3,5,7,8)
		Drury, C., & Clement, M. (1978). The effect of area, density, and number opf background characters on visual search. *Human Factors, 20,* 597-602.
		Silbernagel, B.L. (1982). Using realistic sensor target and scene characteristics to develop a target acquisition model. *Human Factors, 24,* 321-328.
		Williams, A., & Weisstein, N. (1978). Line segments are perceived better in a coherent context than alone: An object-line effect. *Memory and Cognition, 6,* 85-90.
1.1.2.2.	Acquisition Mode	
1.1.2.2.1	Target Detection	Biederman, I. (1972). Perceiving real-world scenes. *Science, 177,* 77-79.
		Biederman, I., Glass, A.L., & Stacy, E.W., Jr. (1973). Searching for objects in real-world scenes. *Journal of Experimental Psychology, 97,* 22-27.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.624-7; 1.653,4)
		Neisser, U., & Becklen, R. (1975). Selective looking: Attending to visually specified events. *Cognitive Psychology, 7,* 480-494.
1.1.2.2.2	Target Identification	Biberman, L.M. (1973). *Perception of displayed information.* NY: Plenum Press.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.655; 7.613,4)
		Brainard, R.W., & Marshall, R.H. (1965, January). *Resolution requirements for identification of targets in television imagery* (NA-63H-794). Columbus, OH: North American Aviation. (DTIC No. AD744902)
		Erickson, R.A., & Hemingway, J.C. (1970, September). *Image identification on television* (NWC-TP-5025). (DTIC No. AD876331)

Taxonomy Category		References
1.1.2.2.3	Target Recognition	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 6.321; 7.526; 11.104,5,7) Reed, S.K. (1972). Pattern recognition and categorization. *Cognitive Psychology, 3*, 382-407. Restle, F. (1982). Coding theory as an integration of Gestalt psychology and information processing theory. In J. Beck (Ed.), *Organization and representation in perception*. Hillsdale, NJ: Erlbaum. Selfridge, O.G., & Neisser, U. (1960). Pattern recognition by machine. *Scientific American, 203*, 60-68.
1.1.2.2.4	Target Localization	Bacon, J.H., Gordon, A., & Schulman, P.H. (1982). The effect of two types of induced-motion displays on perceived location of the induced target. *Perception & Psychophysics, 32*, 353-359. Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 5.601,4-7; 7.614) Matin, L. (1986). Visual localization and eye movements. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. New York: Wiley. Ward, F. (1976). Pursuit eye movements and visual localization. In R.A. Monty & J.W. Senders (Eds.), *Eye movements and psychological processes* (pp. 289-297). Hillsdale, NJ: Erlbaum.
1.1.2.3	Distance Determination	Ellis, S.R., Smith, S., & Hacisalihzade, S. (1990, March). Visualization of three dimensional data. *In NASA, Lyndon B Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (Soar 1989)*, 465-469. Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.640; 1.808; 1.952; 5.105; 5.901,2,4,6) Gold, T. (1972). The limits of stereopsis for depth perception in dynamic visual situations. *International Symposium & Seminar (72E06)*, Vol. II. New York: Society for Information Display.

Taxonomy Category		References
		Haber, R.N., & Hershenson, M. (1973). *The psychology of visual perception.* New York: Holt, Rinehart, & Winston.
		Harker, G.S., & Henderson, A.C. (1956). Effect of vertical misalignment of optical images on depth judgments. *Journal of the Optical Society of America, 46,* 841-845.
		Sedgewick, H.A. (1986). DSpace perception. In K.R. Boff, L. Kaufman, L.,& J.P. Thomas. (Eds.), *Handbook of perception and human peformance: Vol. I. Sensory processes and perception.* New York: Wiley.
1.1.2.4	Motion Determination	
1.1.2.4.1	Motion Detection	Bartlett, N., Brown, J., Hsia, Y., & Mueller, C. (1965). In C. Graham (Ed.), *Vision and visual perception.* New York: Wiley.
		Biederman-Thorson, M., Thorson, J., & Lange, G.D. (1971). Apparent movement due to closely spaced sequentially flashed dots in the human peripheral field of vision. *Vision Research, 11,* 889-903.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.637; 5.203,5,6,7; 6.316)
		Brown, J. (1931). The thresholds for visual movement. *Psychologische Forschung, 14,* 249-268.
		Brown, R. (1957). The effect of extent on the intensity-time relation for the visual discrimination of movement. *Journal of Comparative and Physiological Psychology, 50,* 109-114.
		Brown, R., & Conklin, J. (1954). The lower threshold of visible movement as a function of exposure time. *The American Journal of Psychology, 67,* 104-110.
		Leibowitz, H.W., & Lomont, J.F. (1954). *The effect of luminance and exposure time upon perception of motion* (WADC-TR-54-78). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD035163)
		McColgin, F.H. (1960). Movement thresholds in peripheral vision. *Journal of the Optical Society of America, 50,* 774-779.

Taxonomy Category		References
		Miller, J., & Ludvigh, E. (1961). The perception of movement persistence in the Ganzfeld. *Journal of the Optical Society of America, 51,* 57-60.
		Shaffer, O., & Wallach, H. (1966). Extent of motion thresholds under subject-relative and object-relative conditions. *Perception & Psychophysics, I,* 447-451.
1.1.2.4.2	Apparent Motion	Aarons, L. (1964). Visual apparent movement research: Review, 1935-1955, and bibliography, 1955-1963. *Perceptual and Motor Skills, 18,* 239-274.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 5.401-4)
		Burt, P., & Sperling, G. (1981). Time, distance and feature tradeoffs in visual apparent motion. *Psychological Review, 88,* 171-195.
		Graham, C.H. (1965). Perception of movement. In C.H. Graham (Ed.), *Vision and visual perception* (pp. 575-588). New York: Wiley.
		Kolers, P.A. (1972). *Aspects of motion perception.* New York: Pergamon.
		Zeeman, W., & Roelofs, C. (1953). Some aspects of apparent motion. *Acta Psychologica, 9,* 158-181.
1.1.2.4.3	Relative Motion	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 1.617; 5.201,2,3)
		Graham, C.H. (1965). Perception of movement. In C.H. Graham (Ed.), *Vision and visual perception* (pp. 575-588). New York: Wiley.
		Harvey, L.O., & Michon, J.A. (1974). Detectability of relative motion as a function of exposure duration, angular separation, and background. *Journal of Experimental Psychology, 103,* 317-325.
		Shaffer, O., & Wallach, H. (1966). Extent of motion thresholds under subject-relative and object-relative conditions. *Perception & Psychophysics, I,* 447-451.
1.1.2.4.4	Collision Prediction	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 5.213,4)

Taxonomy Category		References
		Rosenbaum, D.A. (1975). Perception and extrapolation of velocity and acceleration. *Journal of Experimental Psychology: Human Perception and Performance, 1*, 395-405.
		Runeson, S. (1975). Visual prediction of collision with natural and non-natural motion functions. *Perception & Psychophysics, 18*, 261-266.
		Schiff, W., & Detwiler, M.L. (1979). Information used in judging impending collisions. *Perception, 8*, 647-658.
1.1.2.5	Textual/Numeric Acquisition	
1.1.2.5.1	Character Font Size & Spacing	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 1.644; 8.113; 11.108,9,11,12,15,16)
		Tufte, E. (1983). *Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press.
1.2	Auditory Modality	Wenzel, E.M., & Foster, S.H. (1990, March). Realtime digital synthesis of virtual acoustic environments. *Computer Graphics 1990 Symposium on Interactive 3D Graphics, 24*(2). Snowbird, UT, USA.
1.2.1	Non-Speech Signals	
1.2.1.1	Signal Detectability	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 2.301-315; 5.1001)
		Green, D.M., Birdsall, T.G., & Tanner, W.P., Jr (1957). Signal detection as a function of signal intensity and duration. *Journal of the Acoustical Society of America, 29*, 523-531.
		Killion, M.C. (1978). Revised estimate of minimum audible pressure: Where is the "missing 6 dB"? *Journal of the Acoustical Society of America, 63*, 1501-1508.
		Licklider, J.C.R. (1951). Basic correlates of the auditory stimulus. In S.S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 985-1039). New York: Wiley.
		Stevens, S.S., & Davis, H. (1938). *Hearing*. New York: Wiley.

Taxonomy Category		References
1.2.1.2	Masking And Interference	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.306-9; 2.313; 8.306)
		Egan, J.P., & Hake, H.W. (1950). On the masking pattern of a simple auditory stimulus. *Journal of the Acoustical Society of America, 22,* 622-630.
		Ehmer, R.H. (1959). Masking patterns of tones. *Journal of the Acoustical Society of America, 31,* 1115-1120.
		Fastl, H. (1976/77). Temporal masking effects: II. Critical band noise masker. *Acustica, 36,* 317-331.
		Fidell, S., Horonjeff, R., Teffeteller, S., & Green, D.M. (1983). Effective masking bandwidths at low frequencies. *Journal of the Acoustical Society of America, 73,* 628-638.
		Garner, W.R., & Miller, G.P. (1947). The masked threshold of pure tones, *Journal of Experimental Psychology, 37,* 293-303.
		Hawkins, J.E., Jr., & Stevens, S.S. (1950). The masking of pure tones and speech by white noise. *Journal of the Acoustical Society of America, 22,* 6-15.
		Patterson, R.D., & Green, D.M. (1978). Auditory masking. In E.C. Carterette & M.P. Friedman (Eds.), *Handbook of perception, Vol IV* (pp. 3337-360). New York: Academic Press.
		Zwicker, E. (1965). Temporal effects in simultaneous masking and loudness. *Journal of the Acoustical Society of America, 38,* 132-141.
1.2.1.3	Environmental Effects (Ambiance)	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 10.311,312)
		Davis, H., Morgan, C.T., Hawkins, J.E., Galambos, R., & Smith, F. (1943). Temporary deafness following exposure to loud tones and noise (Contract OEM-CMR-194). Boston, MA; Harvard Medical School, Committee of Medical Research, Office of Scientific Research and Development.
		Harris, J.D. (1967). Relations among aftereffects of acoustic stimulation. *Journal of the Acoustical Society of America, 43,* 1306-1324.

Taxonomy Category		References
		Hecker, M.H.L., & Kryter, K.D. (1964). *A study of auditory fatigue cased by high intensity acoustic transients* (Rep. No. 1158). Washington, DC: U.S. Army Medical Research and Development Command, Office of the Surgeon General. (DTIC No. AD450707)
		Kryter, K.D., & Garinther, G. (1966). Auditory effects of acoustic impulses from firearms. *Acta Oto-Laryngologica, Suppl.211*.
		Mills, J.H., Gilbert, R.M., & Adkins, W.Y. (1979). Temporary threshold shifts in humans exposed to octave bands of noise for 16-24 hours. *Journal of the Acoustical Society of America, 65*, 1238-1248.
		Speith, W., & Trittipoe, W.J. (1958). Intensity and duration of noise exposure and temporary shifts. *Journal of the Acoustical Society of America, 30*, 710-713.
		Ward, W.D., Glorig, A, & Sklar, D.L. (1958). Dependence of the temporary threshold shift at 4KC on intensity and time. *Journal of the Acoustical Society of America, 30,* 944-954.
1.2.1.4	Localization Of Signals	Blauert, J. (1983). *Spatial hearing: The psychophysics of human sound localization.* Cambridge, MA: MIT Press.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.810,12,13; 5.1127; 8.301)
		Durlach, N.I., & Colburn, H.S. (1978). Binaural phenomena. In E.C. Carterette, & M.P. Friedman (Eds.), *Handbook of perception IV: Hearing* (pp. 365-466). New York: Academic Press.
		Fedderson, W.E., Sandel, T.T., Teas, D.C., & Jeffress, L.A. (1957). Localization of high-frequency tones. *Journal of the Acoustical Society of America, 29*, 988-991.
		Jeffress, L.A., & Taylor, R.of W. (1961). Lateralization versus localization. *Journal of the Acoustical Society of America, 33,* 482-483.
		Lackner, J.R. (1973). The role of posture in sound localization. *Quarterly Journal of Experimental Psychology, 26*, 235-251.

Taxonomy	Category	References
		Loomis, J.M., Hebert, C., & Cicinelli, J.G. (1990). Active localization of virtual sounds. *Journal of the Acoustic Society of America, 88,* 1757-1764.
		Molino, J.A. (1974). Psychophysical verification of predicted interaural differences in localizing distant sound sources. *Journal of the Acoustical Society of America, 55,* 139-147.
		Scharf, B., Florentine, M., & Meiselman, C.H. (1976). Critical band in auditory lateralization. *Sensory Process, 1,* 109-126.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Stevens, S.S., & Newman, E.B. (1936). The localization of actual sources of sound. *American Journal of Psychology, 48,* 297-306.
1.2.1.5	Pitch Considerations (Signal Frequency)	Berger, E.H. (1981). Re-examination of the low-frequency (50-1000 Hz) normal threshold of hearing in free and diffuse sound fields. *Journal of Acoustical Society of America, 70, 1635-1645.*
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.302; 2.701,4,8,9)
		Robinson, D.W., & Dadson, R.S. (1956). A redetermination of the equal-loudness relations for pure tones. *British Journal of Applied Physics, 7,* 166-181.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
1.2.1.6	Loudness (Signal Intensity) Considerations	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.601; 2.606; 2.608; 2.612)
		Green, D.M., Birdsall, T.G., & Tanner, W.P., Jr (1957). Signal detection as a function of signal intensity and duration. *Journal of the Acoustical Society of America, 29,* 523-531.

Taxonomy Category		References
		Killion, M.C. (1978). Revised estimate of minimum audible pressure: Where is the "missing 6 dB"? *Journal of the Acoustical Society of America, 63*, 1501-1508.
		Robinson, D.W., & Dadson, R.S. (1956). A redetermination of the equal-loudness relations for pure tones. *British Journal of Applied Physics, 7*, 166-181.
		Scharf, B., (1983). Loudness adaptation. In J.V. Tobias & E.D. Schubert (Eds.), *Hearing research and theory*. New York: Academic Press.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. New York: Wiley.
		Zwicker, E. (1965). Temporal effects in simultaneous masking and loudness. *Journal of the Acoustical Society of America, 38*, 132-141.
		Zwicker, E., & Scharf, B. (1965). A model of loudness summation. *Psychological Review, 72*, 3-26.
1.2.1.7	Signal To Noise Relationships	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 2.311)
		Garner, W.R., & Miller, G.P. (1947). The masked threshold of pure tones, *Journal of Experimental Psychology, 37*, 293-303.
		Hawkins, J.E., Jr., & Stevens, S.S. (1950). The masking of pure tones and speech by white noise. *Journal of the Acoustical Society of America, 22*, 6-15.
		Kryter, K.D. (1970). *The effects of noise on man*. New York: Academic Press.
1.2.1.8	Sound Fidelity	
1.2.2	Speech Signals	
1.2.2.1	Signal Detectability	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 2.301-315; 8.304)

Taxonomy Category		References
		Green, D.M., Birdsall, T.G., & Tanner, W.P., Jr (1957). Signal detection as a function of signal intensity and duration. *Journal of the Acoustical Society of America, 29,* 523-531.
		Killion, M.C. (1978). Revised estimate of minimum audible pressure: Where is the "missing 6 dB"? *Journal of the Acoustical Society of America, 63,* 1501-1508.
		Licklider, J.C.R. (1951). Basic correlates of the auditory stimulus. In S.S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 985-1039). New York: Wiley.
		Stevens, S.S., & Davis, H. (1938). *Hearing.* New York: Wiley.
1.2.2.2	Masking And Interference	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.306-9; 8.305,6,7)
		Egan, J.P., & Hake, H.W. (1950). On the masking pattern of a simple auditory stimulus. *Journal of the Acoustical Society of America, 22,* 622-630.
		Ehmer, R.H. (1959). Masking patterns of tones. *Journal of the Acoustical Society of America, 31,* 1115-1120.
		Fastl, H. (1976/77). Temporal masking effects: II. Critical band noise masker. *Acustica, 36,* 317-331.
		Fidell, S., Horonjeff, R., Teffeteller, S., & Green, D.M. (1983). Effective masking bandwidths at low frequencies. *Journal of the Acoustical Society of America, 73,* 628-638.
		Garner, W.R., & Miller, G.P. (1947). The masked threshold of pure tones, *Journal of Experimental Psychology, 37,* 293-303.
		Hawkins, J.E., Jr., & Stevens, S.S. (1950). The masking of pure tones and speech by white noise. *Journal of the Acoustical Society of America, 22,* 6-15.
		Patterson, R.D., & Green, D.M. (1978). Auditory masking. In E.C. Carterette & M.P. Friedman (Eds.), *Handbook of perception, Vol IV* (pp. 3337-360). New York: Academic Press.
		Zwicker, E. (1965). Temporal effects in simultaneous masking and loudness. *Journal of the Acoustical Society of America, 38,* 132-141.

Taxonomy Category		References
1.2.2.3	Environmental Effects (Ambiance)	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 10.311,312)
		Davis, H., Morgan, C.T., Hawkins, J.E., Galambos, R., & Smith, F. (1943). Temporary deafness following exposure to loud tones and noise (Contract OEM-CMR-194). Boston, MA; Harvard Medical School, Committee of Medical Research, Office of Scientific Research and Development.
		Harris, J.D. (1967). Relations among aftereffects of acoustic stimulation. *Journal of the Acoustical Society of America, 43,* 1306-1324.
		Hecker, M.H.L., & Kryter, K.D. (1964). *A study of auditory fatigue cased by high intensity acoustic transients* (Rep. No. 1158). Washington, DC: U.S. Army Medical Research and Development Command, Office of the Surgeon General. (DTIC No. AD450707)
		Kryter, K.D., & Garinther, G. (1966). Auditory effects of acoutic impulses from firearms. *Acta Oto-Laryngologica, Suppl.211.*
		Mills, J.H., Gilbert, R.M., & Adkins, W.Y. (1979). Temporary threshold shifts in humans exposed to octave bands of noise for 16-24 hours. *Journal of the Acoustical Society of America, 65,* 1238-1248.
		Speith, W., & Trittipoe, W.J. (1958). Intensity and duration of noise exposure and temporary shifts. *Journal of the Acoustical Society of America, 30,* 710-713.
		Ward, W.D., Glorig, A, & Sklar, D.L. (1958). Dependence of the temporary threshold shift at 4KC on intensity and time. *Journal of the Acoustical Society of America, 30,* 944-954.
1.2.2.4	Localization Of Signals	Blauert, J. (1983). *Spatial hearing: The psychophysics of human sound localization.* Cambridge, MA: MIT Press.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.812,14,16; 5.1006; 5.1127)
		Durlach, N.I., & Colburn, H.S. (1978). Binaural phenomena. In E.C. Carterette, & M.P. Friedman (Eds.), *Handbook of perception IV: Hearing* (pp. 365-466). New York: Academic Press.

Taxonomy Category		References
		Fedderson, W.E., Sandel, T.T., Teas, D.C., & Jeffress, L.A. (1957). Localization of high-frequency tones. *Journal of the Acoustical Society of America, 29*, 988-991.
		Gardner, M.B. (1969). Distance estimation of 0° or apparent 0°-oriented speech in anechoic space. *Journal of the Acoustical Society of America, 45, 47-53.*
		Jeffress, L.A., & Taylor, R.of W. (1961). Lateralization versus localization. *Journal of the Acoustical Society of America, 33,* 482-483.
		Lackner, J.R. (1973). The role of posture in sound localization. *Quarterly Journal of Experimental Psychology, 26*, 235-251.
		Loomis, J.M., Hebert, C., & Cicinelli, J.G. (1990). Active localization of virtual sounds. *Journal of the Acoustic Society of America, 88*, 1757-1764.
		Molino, J.A. (1974). Psychophysical verification of predicted interaural differences in localizing distant sound sources. *Journal of the Acoustical Society of America, 55*, 139-147.
		Scharf, B., Florentine, M., & Meiselman, C.H. (1976). Critical band in auditory lateralization. *Sensory Process, 1*, 109-126.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Stevens, S.S., & Newman, E.B. (1936). The localization of actual sources of sound. *American Journal of Psychology, 48*, 297-306.
1.2.2.5	Pitch Considerations (Signal Frequency)	Berger, E.H. (1981). Re-examination of the low-frequency (50-1000 Hz) normal threshold of hearing in free and diffuse sound fields. *Journal of Acoustical Society of America, 70, 1635-1645.*
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.302; 2.704,8,9)
		Robinson, D.W., & Dadson, R.S. (1956). A redetermination of the equal-loudness relations for pure tones. *British Journal of Applied Physics, 7*, 166-181.

Taxonomy	Category	References
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. New York: Wiley.
1.2.2.6	Loudness (Signal Intensity) Considerations	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 8.203,4; 8.312; 8.317)
		Green, D.M., Birdsall, T.G., & Tanner, W.P., Jr (1957). Signal detection as a function of signal intensity and duration. *Journal of the Acoustical Society of America, 29*, 523-531.
		Killion, M.C. (1978). Revised estimate of minimum audible pressure: Where is the "missing 6 dB"? *Journal of the Acoustical Society of America, 63*, 1501-1508.
		Robinson, D.W., & Dadson, R.S. (1956). A redetermination of the equal-loudness relations for pure tones. *British Journal of Applied Physics, 7*, 166-181.
		Scharf, B., (1983). Loudness adaptation. In J.V. Tobias & E.D. Schubert (Eds.), *Hearing research and theory*. New York: Academic Press.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. New York: Wiley.
		Zwicker, E. (1965). Temporal effects in simultaneous masking and loudness. *Journal of the Acoustical Society of America, 38*, 132-141.
		Zwicker, E., & Scharf, B. (1965). A model of loudness summation. *Psychological Review, 72*. 3-26.
1.2.2.7	Signal To Noise Relationships	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 8.304,5)
		Garner, W.R., & Miller, G.P. (1947). The masked threshold of pure tones, *Journal of Experimental Psychology, 37*, 293-303.
		Hawkins, J.E., Jr., & Stevens, S.S. (1950). The masking of pure tones and speech by white noise. *Journal of the Acoustical Society of America, 22*, 6-15.

Taxonomy Category		References
		Kryter, K.D. (1970). *The effects of noise on man.* New York: Academic Press.
1.2.2.8	Sound Fidelity	
1.2.3	Acoustic Target Acquisition	
1.2.3.1	Target Characteristics	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.815; 3.119)
		Geldard, F.A. (1982). Saltation in somesthesis. *Psychological Bulletin, 92,* 136-175.
1.2.3.2	Acquisition Mode	
1.2.3.2.1	Target Detection	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.815; 3.119; 5.1006)
1.2.3.2.2	Target Identification	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio.. (Section 2.801; 2.815; 3.119; 5.1006)
1.2.3.2.3	Target Recognition	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.815; 3.119; 5.1006)
1.2.3.2.4	Target Localization	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.815; 3.119; 5.1006)
1.2.3.3	Localization	Blauert, J. (1983). *Spatial hearing: The psychophysics of human sound localization.* Cambridge, MA: MIT Press.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.801; 2.805,6,7; 2.814)
		Durlach, N.I., & Colburn, H.S. (1978). Binaural phenomena. In E.C. Carterette, & M.P. Friedman (Eds.), *Handbook of perception IV: Hearing* (pp. 365-466). New York: Academic Press.

Taxonomy Category		References
		Fedderson, W.E., Sandel, T.T., Teas, D.C., & Jeffress, L.A. (1957). Localization of high-frequency tones. *Journal of the Acoustical Society of America, 29*, 988-991.
		Jeffress, L.A., & Taylor, R.of W. (1961). Lateralization versus localization. *Journal of the Acoustical Society of America, 33,* 482-483.
		Lackner, J.R. (1973). The role of posture in sound localization. *Quarterly Journal of Experimental Psychology, 26,* 235-251.
		Molino, J.A. (1974). Psychophysical verification of predicted interaural differences in localizing distant sound sources. *Journal of the Acoustical Society of America, 55,* 139-147.
		Scharf, P., Florentine, M., & Moiselman, C.H. (1976). Critical band in auditory lateralization. *Sensory Process, 1,* 109-126.
		Scharf, B., & Houtsma, A. (1986). Audition II: Loudness, pitch, localization, aural distortion, pathology. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Stevens, S.S., & Newman, E.B. (1936). The localization of actual sources of sound. *American Journal of Psychology, 48,* 297-306.
1.3	Vestibular Modality	Badler, N.I., O'Rourke, J., & Kaufman, B. (1980). Special problems in human movement simulation. *Proceedings of the ACM SIGGRAPH 80, Computer Graphics, Volume 14, No. 2,* 189-197.
		Lackner, J.R., & DiZio, P. (1984). Some efferent and somatosensory influences on body orientation and oculomotor control. In: L. Spillman & B.R. Wooten (Eds), *Sensory Experience, Adaptation and Perception,* 281-301. NJ: Erlbaum Associates.
1.3.1	Vestibular Sensitivity	
1.3.1.1	Angular Acceleration	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.208; 10.901,3,4)
		Braunstein, M.L., & White, W.J. (1962). The effects of acceleration on brightness discrimination. *Journal of the Optical Society of America, 52,* 931-933.

Taxonomy Category		References
		Clark, B. (1967). Thresholds for the perception of angular acceleration in man. *Aerospace Medicine, 38*, 443-450.
		Clark, B., & Stewart, J.D. (1968). Comparison of three methods to determine thresholds for perception of angular acceleration. *American Journal of Psychology, 81*, 207-216.
		Groen, J.J., & Jongkees, L.B.W. (1948). The threshold of angular acceleration perception. *Journal of Physiology, 107*, 1-7.
		White, W.J. (1960). *Variations in absolute visual thresholds during acceleration stress* (ASD-TR-60-34). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division, (DTIC No. AD243612)
1.3.1.2	Linear Acceleration	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.206,7; 10.901,3,4)
		Braunstein, M.L., & White, W.J. (1962). The effects of acceleration on brightness discrimination. *Journal of the Optical Society of America, 52*, 931-933.
		Melvill Jones, G., & Young, L.R. (1978). Subjective detection of vertical acceleration: A velocity-dependent response. *Acta Otolaryngologica, 85*, 45-53.
		Parker, D.E., Gulledge, W.L., Tubbs, R.L. & Littlefield, V.M. (1978). A temporary threshold shift for self-motion detection following sustained oscillating acceleration. *Perception & Psychophysics, 23*, 461-467.
		Walsh, E.G. (1962). The perception of rhythmically repeated linear motion in the horizontal plane. *British Journal of Psychology, 53*, 439-445.
		Walsh, E.G. (1964). The perception of rhythmically repeated linear motion in the vertical plane. *Quarterly Journal of Experimental Psychology, 49*, 58-65.
		White, W.J. (1960). *Variations in absolute visual thresholds during acceleration stress* (ASD-TR-60-34). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division, (DTIC No. AD243612)

Taxonomy Category		References
1.3.1.3	Body Rotation	Bles, W. (1981). Stepping around: Circular vection and Coriolis effects. In J. Long & A. Baddeley (Eds.) *Attention and performance IX.* Hillsdale, NJ: Erlbaum.
		Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.204,5,10; 5.503,4)
		Brandt, T., Wist, E.R., & Dichgans, J. (1975). Foreground and background in dynamic spatial orientation. *Perception & Psychophysics, 17,* 497-503.
		Guedry, F.E., Lentz, J.M., & Jell, R.M. (1979). Visual-vestibular interactions: I. Influence of peripheral vision on suppression of the vestibuo-ocular reflex and visual acuity. *Aviation, Space and Environmental Medicine, 50,* 205-211.
		Guedry, F.E., Lentz, J.M., Jell, R.M., & Norman, J.W. (1981). Visual-vestibular interactions: II. The directional component of visual background movement. *Aviation, Space and Environmental Medicine, 52,* 304-309.
		Howard, J.P. (1986). The perception of posture, self motion, and the visual vertical. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.) *Handbook of Perception and Human Performance: Vol. I. Sensory processes and perception.* New York: Wiley.
1.3.1.4	Adaptation	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.209; 10.904,6)
		White, W.J. (1961). Visual performance under gravitational stress. In O.H. Gauer & G.D. Zuidema (Eds.), *Gravitational stress in aerospace medicine* (pp. 70-89). Boston: Little, Brown & Company
1.3.1.5	Vibration	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 10.401,2; 10.427)
		Griffin, M.J. (1986). *Evaluation of vibration with respect to human response* (SAE 860047). Warrendale, PA: Society of Automotive Engineers. International Organization for Standardization (1974). *Guide for the evaluation of human exposure to whole-body vibration* (ISO 2631). Geneva: ISO.

Taxonomy Category		References
		International Organization for Standardization (1982). *Guide for the evaluation of human exposure to whole-body vibration. Amendment I* (ISO 2631-1978/A1-1982). Geneva: ISO.
		McKay, J.R. (1971). *Human perception of whole-body vibration* (Memorandum No. 435). Southampton, England: University of Southampton, Institute of Sound and Vibration Research
		Parsons, K.C. (1981). *Vibration perception thresholds and the application to building vibration.* Paper presented to the United Kingdom Informal Group Meeting on Human Response to Vibration, Heriot-Watt University, Edinburgh, Scotland.
		Parsons, K.C. (1981). *Whole body vibration perception thresholds of sitting, standing and lying subjects.* Paper presented to the United Kingdom Information Group Meeting on Human Response to Vibration, National Institute of Agricultural Engineering/National College of Agricultural Engineering, Silsoe, Berkshire, England.
1.4	Proprioception	Badler, N.I., O'Rourke, J., & Kaufman, B. (1980). Special problems in human movement simulation. *Proceedings of the ACM SIGGRAPH 80, Computer Graphics, Volume 14, No. 2,* 189-197.
		Goodwin, G.M., McCloskey, D.I., & Mathews, P.B.C. (1972). Proprioceptive illusions induced by muscle vibration: Contribution by muscle spindles to perception? *Science, 175,* 1382-1384.
		Lackner, J.R., & DiZio, P. (1984). Some efferent and somatosensory influences on body orientation and oculomotor control. In: L. Spillman & B.R. Wooten (Eds), *Sensory Experience, Adaptation and Perception,* 281-301. NJ: Erlbaum Associates.
1.4.1	Gross Motor Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.301-321; 9.537))
		Brown, J.S., Knauft, E.B., & Rosenbaum, G. (1948). The accuracy of positioning reaction as a function of their direction and extent. *American Journal of Psychology, 61,* 167-182.

Taxonomy Category		References
		Caldwell, L.S. (1956). *The accuracy of constant angular displacement of the arm in the horizontal place as influenced by the direction and locus of the primary adjustive movement* (Rep. No. 233, pp. 1-16). Fort Knox, KY: Army Medical Research Laboratory.
		Collins, J.K. (1971). Isolation of the muscular component in a proprioceptive spatial aftereffect. *Journal of Experimental Psychology, 90*, 287-299.
		Craske, B., & Crawshaw, M. (1974). Differential errors of kinesthesis produced by previous limb position. *Journal of Motor Behavior, 6*, 273-278.
		Craske, B., & Crawshaw, M. (1975). Shifts in kinethesis through time and after active and passive movements. *Perceptual and Motor Skills, 40*, 755-761.
		Howard, I.P., & Anstis, T. (1974). Muscular and joint-receptor components in postural persistence. *Journal of Experimental Psychology, 103*, 167-170.
		Paillard, J., & Brouchon, M. (1968). Active and passive movements in the calibration of position sense. In S.J. Freedman (Ed.), *The neuropsychology of spatially oriented behavior* (pp. 37-55). Homewood, IL: Dorsey.
		Paillard, J., & Brouchon, M. (1974). A proprioceptive contribution to the spatial encoding of position cues for ballistic movements. *Brain Research, 71*, 273-284.
1.4.2	Fine Motor Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 3.307,318; 9.537)
		Gandevia, S.C., Hall, L.A., McCloskey, D.I., & Potter, E.K. (1983). Proprioceptive sensation at the terminal joint of the middle finger. *Journal of Physiology, 335*, 507-517.
		Gandevia, S.C., & McCloskey, D.I. (1976). Joint sense, muscle sense, and their combination as position sense, measured at the distal interphallangeal joint of the middle finger. *Journal of Physiology, 260*, 387-407.
		Rymer, W.Z., & D'Almeida, A. (1980). Joint position sense: The effects of muscle contraction. *Brain, 103*, 122.

Taxonomy Category		References
1.5	Cutaneous (Tactile) Modality	Kenshalo, D.R. (Ed.). (1979). *Sensory functions of the skin of humans.* New York: Plenum.
		Klatzky, R.L., Lederman, S.J., & Balakrishnan, J.D. (1991, January). Task-driven extraction of object contour by human haptics.1. *Robotica, 9,* 43-51.
		Lederman, S.J., Klatzky, R.L., & Balakrishnan, J.D. (1991, April). Task-driven extraction of object contour by human haptics.2. *Robotica, 9,* 179-188.
1.5.1	Cutaneous Sensitivity	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.101; 3.116,8)
		Johansson, R.S. (1979). Tactile afferent units with small and well demarcated receptive fields in the glabrous skin area of the human hand. In D.R. Kenshalo (Ed.), *Sensory functions of the skin of humans* (pp. 129-152). New York: Plenum.
		Sherrick, C., & Cholewiak, R.W. (1986). Cutaneous sensitivity. In K.R. Boff, L. Kaufman & J.P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception.* New York: Wiley.
		Sinclair, D.C. (1967). *Cutaneous sensation.* London: Oxford University Press.
1.5.2	Pattern Discrimination	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio (Section 3.101,2; 6.502-7)
		Craig, J.C. (1981). Tactile letter recognition: Pattern duration and modes of pattern generation. *Perception & Psychophysics, 30,* 540-546.
		Loomis, J.M. (1974). Tactile letter recognition under different modes of stimulus presentation. *Perception & Psychophysics, 16,* 401-408.
		Loomis, J. M. (1980). Interaction of display mode and character size in vibrotactile letter recognition. *Bulletin of the Psychonomic Society, 16,* 385-387.
1.5.3	Thermal Sensitivity	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.101; 3.122,3,4)

Taxonomy Category		References
		Kenshalo, D.R. (1970). Psychophysical studies of temperature sensitivity. In W.D. Neff (Ed.), *Contributions to sensory physiology*. New York: Academic Press.
		Kenshalo, D.R., Holmes, C.E., & Wood, P.B. (1968). Warm and cool thresholds as a function of rate of stimulus temperature change. *Perception & Psychophysics, 3*, 81-84.
		Lele, P.P. (1954). Relationship between cutaneous thermal thresholds, skin temperature and cross-sectional area of stimulus. *Journal of Physiology (London), 126*, 191-205.
1.5.4	Force Feedback Considerations	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 9.501,6,7; 9.537)
		Carello, C., Fitzpatrick, P., & Turvey, M. (1992). Haptic probing - perceiving the length of a probe and the distance of a surface probed. *Perception & Psychophysics, 51*(6), 580-598.
		Sanders, Mark S. and McCormick, Ernest J. (1987). Controls. In J. Anker & J. Morriss (Eds.), *Human factors in engineering and design* (pp. 270-273, 293-294). New York: McGraw-Hill.
1.6	Olfactory Modality	
1.6.1	Sensitivity (Detection)	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance*. Wright-Patterson Air Force Base, Ohio. (Section 5.1001)
		Deatherage, Bruce H. (1972). Auditory and other sensory forms of information presentation. In H.P. Van Cott, & R.G. Kinkade (Eds.), *Human engineering guide to equipment design* (pp. 155-156). Washington, D.C.: American Institutes for Research.
		Matlin, Margaret W. (1983). Smell. In Margaret W. Matlin (Ed.), *Perception* (pp. 224-243). Newton, Mass: Allyn and Bacon.
		Pfaffman, C. ([illegible]). Taste and smell. In S.S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 1143-1171). New York: Wiley.
1.6.2	Location/ Orientation Discrimination	

Taxonomy	Category	References
2	Behavioral Considerations - Output	
2.1	Speech	
2.1.1	Continuous/ Discrete	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 8.201)
2.1.2	Vocabulary Size	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 8.304,8,9,17)
2.1.3	Speaker Dependence	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio.(Section 8.304,8,9,17)
2.1.4	Background Noise Sensitivity	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio.(Section 2.301-6; 8.304)
2.2.1	Psychomotor Movement	Clark, F.J. & Horch, K.W. (1986) Kinesthesia. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.). *Handbook of perception and human performance: Vol I. Sensory processes and perception.* New York: Wiley.
2.2.1.1	Hand Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.309-321; 9.537)
2.2.1.2	Finger Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.318; 9.537) Clark, F.J., Burgess, R.C., & Chapin, J.W. (1983). Humans lack of sense of static-position of the fingers. *Society for Neuroscience Abstracts, 9,* 1033. Gandevia, S.C., Hall, L.A., McCloskey, D.I., & Potter, E.K. (1983). Proprioceptive sensation at the terminal joint of the middle finger. *Journal of Physiology, 335,* 507-517. Gandevia, S.C., & McCloskey, D.I. (1976). Joint sense, muscle sense, and their combination as position sense, measured at the distal interphallangeal joint of the middle finger. *Journal of Physiology, 260,* 387-407.

Taxonomy Category		References
		Hall, L.A., & McCloskey, D.I. (1983). Detections of movements imposed on finger, elbow and shoulder joints. *Journal of Physiology, 335*, 519-533.
		Rymer, W.Z., & D'Almeida, A. (1980). Joint position sense: The effects of muscle contraction. *Brain, 103*, 122.
2.2.1.3	Head Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 2.814;3.303,8; 3.321; 9.537)
		Howard, I.P., & Anstis, T. (1974). Muscular and joint-receptor components in postural persistence. *Journal of Experimental Psychology, 103*, 167-170.
2.2.1.4	Body Movement	Boff, K. R., and Lincoln, J. E. (Eds.). (1988). *Engineering Data Compendium: Human Perception and Performance.* Wright-Patterson Air Force Base, Ohio. (Section 3.03; 9.537)
		Clark, F.J. & Horch, K.W. (1986) Kinesthesia. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.). *Handbook of perception and human performance: Vol I. Sensory processes and perception.* New York: Wiley.

APPENDIX C TECHNOLOGY PERFORMANCE REQUIREMENTS FOR INDIVIDUAL COMBATANT ACTIVITIES

Activity	Taxonomy	Category	Performance Requirement
Use password	2.1	Speech - Output	Low
Give verbal orders	2.1	Speech - Output	Medium to High
Call in preplanned fire requests	2.1	Speech - Output	Medium
Carry protective mask	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.1	Hand Movement	Medium
	2.2.1.2	Finger Movement	Medium
	2.2.1.4	Body Movement	High
Administer first aid	1.1.1	Image Quality	Medium
	1.2.1	Non-speech Signals	Low
	1.2.2	Speech Signals	Medium to High
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium to High
	2.1	(Speech - Output)	Medium
	2.2	Position and Orientation	High
Camouflage self (to include face)	1.1.1	Image Quality	Low to Medium
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Inspect condition of feet	1.1.1	Image Quality	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium to High
	2.2	Position and Orientation	High
Search, gag, and tag POWs	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	High
Perform radiological decontamination	1.1.1	Image Quality	Medium to High
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium to High

Activity	Taxonomy	Category	Performance Requirement
			High
	2.2	Position and Orientation	Medium to High
Perform chemical decontamination	1.1.1	Image Quality	
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium to High
	2.2	Position and Orientation	High
Inject Atropine	1.1.1	Image Quality	Low to Medium
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	High
"Kill" a soldier with a weapon	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	High
"Kill" a soldier with hands	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	Medium to High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium to High
	2.2	Position and Orientation	High
Evacuate casualties	1.1.1	Image Quality	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	Medium to High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium
	2.2	Position and Orientation	High
Give hand and arm signals	1.4	Proprioception	Medium
	2.2.1.1	Hand Movement	Medium
	2.2.1.2	Finger Movement	Medium

Activity	Taxonomy	Category	Performance Requirement
Operate chemical-alarm	1.1.1	Image Quality	Low to Medium
	1.1.2.1	Target Characteristics	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.2.1	Non-Speech Signals	Low
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Activate demolitions	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2.1	Non-Speech Signals	Low
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Test fire weapons	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Low
	1.2.2	Speech Signals	Medium
	1.3.1.3,5	Body Rotation & Vibration	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Place weapons on safe	1.1.1	Image Quality	Low
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Prepare DRAGON sight	1.1.1	Image Quality	Medium
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Place LAW in operation	1.1.1	Image Quality	Medium
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Place crew served weapons in operation	1.1.1	Image Quality	Medium
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Change rate of fire	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.2	Finger Movement	Medium
Fire flare to signal	1.1.1	Image Quality	Low
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Blow whistle for signal	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Activate early warning (trip wire) devices	1.1.1	Image Quality	Medium
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Set up and employ Claymore mines	1.1.1	Image Quality	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Set up tug line	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Place filters on flashlight	1.1.1	Image Quality	Low to Medium
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.1-3	Hand, Finger & Head Movement	Medium
Use tug line	1.1.1	Image Quality	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Arm (and employ) hand grenade	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
"Cook off" grenade	1.1.1	Image Quality	Low
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Repair equipment	1.1.1	Image Quality	High
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Prepare demolitions	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	1.4	Proprioception	Medium to High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Bend radio antenna down	1.1.1	Image Quality	Low
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.1	Hand Movement	Medium
	2.2.1.2	Finger Movement	Medium
Set frequency on radio	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.1	Hand Movement	Medium
	2.2.1.2	Finger Movement	Medium
Operate radio or telephone	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.2.2	Speech Signals	Low
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Attach telephone to commo wire	1.1.1	Image Quality	Low to Medium
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Use switchboard	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2.2	Speech Signals	Low
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Check radio instruments	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2	Auditory Modality	Low
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Set up early warning (trip wire) devices	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Operate flashlight	1.1.1.2	Luminance/Spectral	Low
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2.1.1,2	Hand & Finger Movement	Medium
Throw smoke grenade	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Throw grenade	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Throw "cooked off" grenade	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5	Cutaneous (Tactile) Modality	Medium
	2.2	Position and Orientation	High
Throw grenade through entrance to bunker	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Determine if rivers and streams are fordable	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	2.2	Position and Orientation	High
Burn garbage and waste	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Inspect boats	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium
	1.6	Olfactory Modality	Medium to High
	2.1	Speech - Output	Medium to High
	2.2	Position and Orientation	High
Inspect for correct "soldier's load"	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.2.2	Speech Signals	Low
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Inspect Equipment	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	1.6	Olfactory Modality	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Check proper wearing of protective suit	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Inspect boat landing	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	1.6	Olfactory Modality	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark vehicles	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	2.2	Position and Orientation	High
Remove or tape items which may reflect light	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Cover all reflective surfaces	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Waterproof water-sensitive items	1.1.1	Image Quality	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5	Cutaneous (Tactile) Modality	Medium
	2.2	Position and Orientation	High
Assemble crossing equipment (ropes and ponchos)	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Destroy equipment	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Distribute supplies and equipment	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Fill rifle magazines	1.1.1	Image Quality	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Count ammunition	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Count/inventory expendable supplies	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Record observation notes	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.2.1	Non-Speech Signals	Low
	1.2.2	Speech Signals	Low
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Write report on personnel strength	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium

Activity	Taxonomy	Category	Performance Requirement
Write report on equipment status	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Write report on supply status	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Write an NBC report	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Record dosimeter readings	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
Draw control features on map	1.1.1	Image Quality	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
Draw sector sketch	1.1.1	Image Quality	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High

Activity	Taxonomy	Category	Performance Requirement
Draw charts and diagrams	1.1.1	Image Quality	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
Draw range card	1.1.1	Image Quality	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.2	Fine Motor Movement	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
Establish cache	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium to High
	1.2.1	Non-Speech Signals	Medium
	1.2.2	Speech Signals	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Dig hasty fighting position	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium to High
	2.2	Position and Orientation	High
Construct fighting position with overhead cover	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Mark cleared bunker or trench	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark weapon position	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark cleared room	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark mine	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark lanes through minefield	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark taut trip wire	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark LZ/DZ	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Mark routes	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Camouflage boat	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Camouflage fighting position	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Remove signs of presence	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Camouflage trail after passing	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Remove debris from LZ	1.1.1	Image Quality	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Cut slack trip wires	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Employ demolitions to breach mines	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Conduct NBC surveys	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Blow holes in wall	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Activate a landmine	1.1.1	Image Quality	Low to Medium

Activity	Taxonomy	Category	Performance Requirement
	1.2.2	Speech Signals	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5	Cutaneous (Tactile) Modality	Medium to High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Employ smoke pots	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Employ probes (for mines)	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Hang camouflage net	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Secure boat	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Steer a boat	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4.2	Fine Motor Movement	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Clear obstacles	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Lay commo wire	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Clear fields of fire	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	Medium
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low
	1.5.4	Force Feedback Considerations	Low
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Construct 1 or 2 rope bridge	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2 2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Construct obstacle	1.1.1	Image Quality	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Lay wire	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Use NBC equipment to conduct surveys	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Low to Medium
	1.6	Olfactory Modality	Medium to High
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Place wire mesh over windows	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	Medium
	1.4	Proprioception	Medium
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	Medium
Perform radiological decontamination	1.1.1	Image Quality	Low
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High

Activity	Taxonomy Category		Performance Requirement
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Perform chemical decontamination	1.1.1	Image Quality	Low
	1.1.2	Visual Target Acquisition	Low to Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low
	1.5.4	Force Feedback Considerations	Medium
	1.6	Olfactory Modality	Medium to High
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Position chemical alarm	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	Low to Medium
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Low to Medium
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Move upright, tactically	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.3	Acoustic Target Acquisition	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move upright rapidly, tactically	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	1.2.3	Acoustic Target Acquisition	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move upright, reconnoiter	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High
	1.2.3	Acoustic Target Acquisition	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move upright in built-up area, tactically	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High
	1.2.3	Acoustic Target Acquisition	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move with stealth	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move by rush	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High

Activity	Taxonomy	Category	Performance Requirement
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Avoid kicking up dust	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.4	Force Feedback Considerations	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move bent over (when approaching helicopters)	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Crawl	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move by low crawl	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Move by high crawl	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Guide squad and squad members	1.1.1	Image Quality	High
	1.1.2	Visual Target Acquisition	High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Move during limited visibility	1.1.1	Image Quality	Low
	1.1.2	Visual Target Acquisition	Low
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Navigate while afloat	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Enter door, window, hole	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.3	Acoustic Target Acquisition	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Climb on and enter vehicle	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Enter and sit down in aircraft	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Exit from aircraft	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Enter and exit rubber boat	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Enter bunker through rear entrance	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Enter trench	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Sit in vehicle	1.1.1	Image Quality	Low to Medium
	1.2.2	Speech Signals	Low
	2.2	Position and Orientation	High
Dismount vehicle	1.1.1	Image Quality	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Follow route designated on map	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Move to a location on a map	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Move in accordance with directions	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Discern own rate of movement	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	2.2	Position and Orientation	High
Calculate distance moved (pacing and offsets)	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	2.2	Position and Orientation	High
Identify actual squad members	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify actual chain of command	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify a sleeping soldier	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify camouflaged individual	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify activity of personnel	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Count members of the squad	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify ranks	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify enemy soldiers	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify civilians	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify damage to equipment	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Identify side of tank	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
Identify rear of armored vehicle	1.1.1	Image Quality	Low to Medium
	1.1.2	Visual Target Acquisition	Medium
Identify trash on the ground	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
Discriminate between friendly and enemy aircraft	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.3	Vestibular Modality.	High
Identify jet aircraft	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.3	Vestibular Modality.	High
Identify dug in fighting position	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify bunker	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify entrance to bunker	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify blind side of bunker	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Ide[illegible]y obstacles	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
Identify puddles	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify overhanging branches	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify bushes	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify good water crossing site (low banks and at least one tree)	1.1.1	Image Quality	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	2.2	Position and Orientation	High
Identify boat obstacles or hazards	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify shadows	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify hand and arm signals	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify hand and arm signals with night vision devices	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify a stroke (paddling rate)	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify light reflected from shiny objects	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify glow from cigarette	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
Identify flashes from enemy weapons	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
Identify type of injury to a soldier	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Identify extent of injury to soldier	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High

Activity	Taxonomy	Category	Performance Requirement
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Read markings on vehicles	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read written order	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read charts and diagrams	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read watch to tell time	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read standard military symbols on a map	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read dosimeter scale	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read CEOIs	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Read Unit SOP	1.1.1	Image Quality	Low to Medium
	1.1.2.5	Textual/Numeric Acquisition	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Read a map	1.1.1	Image Quality	Medium
	1.1.2.5	Textual/Numeric Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	2.2	Position and Orientation	High
Use binoculars	1.1.1	Image Quality	Medium
	1.4	Proprioception	Medium to High
Use night vision devices	1.1.1	Image Quality	Medium
	1.4	Proprioception	Medium to High
Maintain position relative to other personnel	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Perceive relative position of weapon fire	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
	1.6	Olfactory Modality	Medium to High
	2.2	Position and Orientation	High
Perceive relative position of lights	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Perceive relative position of other units	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Identify restricted fire lines, check points, contact points, phase lines, etc.	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Identify assigned sectors	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Identify dead space	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.1.2.5	Textual/Numeric Acquisition	Medium to High
	1.2.2	Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Determine location of flying aircraft	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.3	Vestibular Modality.	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Determine own or observed location on map to six digit coordinates	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Determine own location on map with respect to map control measures	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Determine azimuth and direction to distant object	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Determine relative location of distant object to known location	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Discern map coordinates of desired location for indirect fire	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Identify orientation of main guns on vehicles	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Identify armored vehicle blind spots	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Identify orientation of soldier's body	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Identify orientation of soldier's field of view	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Identify orientation of soldier's weapon or fire	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	2.2	Position and Orientation	High
Follow azimuth	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Discern direction enemy is moving	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Discern own movement direction	1.1.1	Image Quality	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Determine direction distant aircraft is flying	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.3	Vestibular Modality.	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Visually search for enemy	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Visually search for aircraft	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.3	Vestibular Modality.	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Walk fire across the objective	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Low to Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Move through a building with sensing of where its front is	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Lay wire along final protective fire line	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.2	Speech Signals	Low
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Clear an objective	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3.1.1-3	Angular-Linear Acceleration/Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Discern location within an area	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Shift fires	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Covered and concealed route	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	High
Areas which mask supporting element fires	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
Distribution points for supplies	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Approach to LZ/DZ which is free of tall trees, telephone lines, power lines, or debris	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	2.2	Position and Orientation	High
Safe and danger area	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	High
	1.5.2	Pattern Discrimination	High
	1.5.4	Force Feedback Considerations	High
	2.2	Position and Orientation	High
Firing positions in building	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Firing positions in natural terrain	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Firing positions in urban area	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Overwatch position	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Support position which will enable fire to be placed on enemy	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Steep slopes	1.1.1	Image Quality	Medium to High

Activity	Taxonomy	Category	Performance Requirement
	1.1.2	Visual Target Acquisition	Medium to High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Slopes which must be climbed	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Slopes which can only be climbed with difficulty	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High
Slopes which cannot be climbed	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
LZ (easily identified from the air, firm surface, free of stumps or similar obstacles	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Percent slope	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Estimate distances between two remote points	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.4.1	Gross Motor Movement	High
	2.2.1.3	Head Movement	High
Estimate distance from self to a distant point	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.4.1	Gross Motor Movement	High
	2.2.1.3	Head Movement	High
Estimate distance to flying aircraft	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
	2.2	Position and Orientation	High
Orient map to field of view	1.1.1	Image Quality	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Low to Medium
	1.5.2	Pattern Discrimination	Low to Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Position/sight weapons	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Position antitank mines	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High

Activity	Taxonomy	Category	Performance Requirement
Aim and fire individual weapon	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	Medium to High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Aim and fire crew served weapon	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Aim and fire M203 GL	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.2	Position and Orientation	High
Aim and fire M60 MG	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Aim and fire LAW	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low
	2.2	Position and Orientation	High
Aim, fire, and track DRAGON	1.1.1	Image Quality	Medium

Activity	Taxonomy	Category	Performance Requirement
	1.1.2	Visual Target Acquisition	Medium
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	1
	2.2	Position and Orientation	High
Engage aircraft with small arms	1.1.1	Image Quality	Medium to High
	1.1.2	Visual Target Acquisition	Medium to High
	1.2	Auditory Modality	Medium to High
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Medium
	2.2	Position and Orientation	High
Lay, sight, and arm Claymore mine	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.2	Speech Signals	Low
	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5	Cutaneous (Tactile) Modality	High
	2.1	Speech - Output	Low to Medium
	2.2	Position and Orientation	High
Use compass to determine azimuth readings	1.1.1	Image Quality	Low to Medium
	1.3.1.3	Body Rotation	High
	1.4	Proprioception	Medium to High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium
	2.2	Position and Orientation	High
Location of impact point of indirect fire based on sound	1.2.1	Non-Speech Signals	High
	1.2.3	Acoustic Target Acquisition	High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
Relative position of noise	1.2.1	Non-Speech Signals	High
	1.2.3	Acoustic Target Acquisition	High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High

Activity	Taxonomy	Category	Performance Requirement
ORP locations which are easy to defend for a short time	1.1.1	Image Quality	Medium
	1.1.2	Visual Target Acquisition	Medium
	1.2.1	Non-Speech Signals	Medium to High
	1.2.3	Acoustic Target Acquisition	Medium to High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
Covered and concealed firing positions	1.2.1	Non-Speech Signals	High
	1.2.3	Acoustic Target Acquisition	High
	1.3.1.3	Body Rotation	High
	1.4.1	Gross Motor Movement	High
Identify squad voices	1.2.2	Speech Signals	Medium
Identify enemy voices	1.2.2	Speech Signals	High
Hear orders	1.2.2	Speech Signals	Medium
Hear own movement noise	1.2.1	Non-Speech Signals	Medium to High
Smell smoke from cigarettes	1.6.1	Olfactory Sensitivity (detection)	Medium to High
Feel for pressure probes and trip wires	1.3.1.3	Body Rotation	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium to High
	1.5.2	Pattern Discrimination	Medium to High
	1.5.4	Force Feedback Considerations	High
Feel tug on tug line	1.3	Vestibular Modality	High
	1.4	Proprioception	High
	1.5.1	Cutaneous Sensitivity	Medium
	1.5.2	Pattern Discrimination	Medium
	1.5.4	Force Feedback Considerations	Medium to High
Feel heat and shock of blast wave	1.3	Vestibular Modality	High
	1.4.1	Gross Motor Movement	High
	1.5.3	Thermal Sensitivity	High
	2.2	Position and Orientation	High

APPENDIX D: ACTIVITIES AND TASKS OF INDIVIDUAL COMBATANTS

LEGEND

Technology Requirements. Detailed ratings of the level of performance required by visual, acoustic, tactile, force feedback, olfactory, and kinesthetic cueing systems as appropriate to support each activity, with the following rankings:

1 = Very low difficulty (can use existing technology)
2 = Low to medium difficulty (can use existing technology with modification and integration)
3 = Medium difficulty (will require development of some new technology)
4 = Medium to high difficulty (will require substantial development of new technology)
5 = Very high difficulty (will require a breakthrough in technology to achieve)

Sensory Mode. An assessment of the primary and secondary cueing and response modalities required to perform the activity, with the following coding:

S = Sound
V = Vision
T = Tactile
F = Force feedback

Effector Mode. The method of monitoring the trainee's response.

BO = Body
FI = Finger
HA = Hand
HE = Head
IO = Instrumented Speech
SP = Speech

Transfer Effectiveness. An estimate of the transfer effectiveness of a virtual environment-based training intervention based upon our review of the behavioral and technical literature and experience with similar skill training problems in virtual environments, with the following rankings:

5 = Completely applicable and desirable in terms of cost/effectiveness
4 = Fair applicability
3 = Marginal applicability
2 = Probably can be done but very low cost/effectiveness
1 = No training effectiveness
0 = Uncertain applicability

Activity	Total Occurrences of Activity	# Tasks with this Activity	1 7-3/4-1021 Defend	2 7-3/4-1018 Antiarmor Ambush	3 7-3/4-1007 Overwatch	4 7-3/4-1011 Assault	5 7-3/4-1020 Point Ambush	6 7-3/4-1019 Hasty Ambush	7 7-3/4-1025 Move Tactically	8 7-3/4-1012 Knock Out Bunker	9 7-3/4-1054 Clear Building	10 7-3/4-1044 Occupy Patrol Base	11 7-3/4-1015 Clear Trench Line	12 7-3/4-1008 Disengage	13 7-3/4-1028 Cross Danger Area	14 7-3/4-1014 Breach Obstacle
Give verbal orders	490	67	18	11	12	6	11	10	10	4	2	8	8	10	2	12
Use password	24	12	3		2					1				2		
Blow whistle for signal	13	8	2	1	4	2	1	1	1	1						
Call in preplanned fire requests	11	11	1	1		1	1	1			1					
Inspect for correct "soldier's load"	5	5														
Hear orders	442	66	21	12	11	1	11	11	6	4	2	7	8	9	2	12
Operate radio or telephone	89	41	3	2	1		2	3	1	1		1				3
Identify safe and danger area	68	32	6	4	3	5		1	8	1	1	3	2	2	2	1
Perceive relative position of other units	63	29	5		3		1		5		3	3	2	1		2
Give hand and arm signals	58	21	5	5	1	4	1	5	6			2	3	1	5	
Move in accordance with directions	50	22	3				1			2		3		3	2	
Visually search for enemy	50	27			1					1			2		4	1
Identify hand and arm signals	47	17	5	6			1	3	8		2	2	4	1	4	
Aim and fire individual weapon	45	20	9	1	3	1	3	1		3	3		4	1	1	1
Aim and fire crew served weapon	43	19	10	1	3	1	3			1	3		4	1	1	1
Aim and fire M60 MG	43	17	10	1	7	1	3			1	3		3	1	1	1
Aim and fire M203 GL	41	17	10	1	4	1	3			2	3		3	1	1	1
Identify support position to fire on enemy	40	17	7	4	4	1	1	2	2	2			4			
Maintain position relative to other personnel	37	20		2		1	1		7		3	3			3	
Read standard military symbols on a map	32	17	4			1			1			1				
Identify overwatch position	27	12	7	3	4			1	4	1			1	2		
Identify areas that mask supporting element fires	26	15	1		3	3			4		1	1	1		1	2
Perceive relative position of weapon fire	26	17	6	1	1		1	1	1			1	1	1	1	
Change rate of fire	17	9	2		4	2	1			1	1			2		
Fire flare to signal	13	8	2	1	4	2	1	1	1	1						
Aim and fire LAW	12	6	5	2	1	1					2		1			
Identify obstacles	12	7	1						2							2
Place crew served weapons in operation	12	11	1	1		2		1		1		1				
Identify dead space	12	8	2		1							2			1	
Identify light reflected from shiny objects	12	10					1		1							
Arm hand grenade	11	7	3	1		1	1	1		2			2			
Identify firing positions in urban area	11	3	6		4	1										
Aim, fire, and track DRAGON	10	5	5	1	1	1					2					
Discern location within an area	10	6	1			3							1		1	
Read dosimeter scale	10	6	1													
Set frequency on radio	10	6		2	1		2	3		1						
Identify glow from cigarette	9	9					1					1				
Hear own movement noise	8	5					1		4							
Read CEOIs	8	8				1		1								
Identify firing positions in building	7	4			4	1			1		1					
Identify orientation of soldier's weapon or fire	7	7		1	1			1								1
Identify flashes from enemy weapons	7	7					1				1					

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 7-3/4-1040 Passage of Lines	16 7-3/4-1060 Stay Behind	17 31-5-0110 Establish Surveillance Site	18 31-5-0204 Conduct Recovery Ops.	19 7-3/4-1064 Linkup	20 31-5-0203 Interdict a Target	21 7-3/4-1022 Occupy Assembly Area	22 7-3/4-1047 Consolidate & Reorganize	23 7-3/4-1016 Helicopter Movement	24 7-3/4-1057 Maintain Op. Security	25 31-5-0121 Exfiltrate by Land	26 7-3/4-1055 Defend Built-up Area	27 31-5-0107 Move in Denied Area	28 7-3/4-1041 Occupy Obj. Rally Pt.
Give verbal orders	490	67	12	6	3	11	14	10	9	8	11	6	11	8	3	6
Use password	24	12	5		2	1	1				1		1			
Blow whistle for signal	13	8														
Call in preplanned fire requests	11	11	1	1		1					1					
Inspect for correct "soldier's load"	5	5											1			
Hear orders	442	66	18	7	5	11	17	10	9	8	11	6	12	7	3	5
Operate radio or telephone	89	41	3	2	1		6		3	2		3	3	1		
Identify safe and danger area	68	32	1	2	2	1	1	1		1	1		1		3	
Perceive relative position of other units	63	29		3		6	1	4	3	1	1			3	2	
Give hand and arm signals	58	21				1			4				1	1	1	1
Move in accordance with directions	50	22	12				1			5	3		1	1		1
Visually search for enemy	50	27			2	3		3		2		2	3			
Identify hand and arm signals	47	17							4				1	1		
Aim and fire individual weapon	45	20	1	1				1	1							
Aim and fire crew served weapon	43	19	1	1				1	1							
Aim and fire M60 MG	43	17	1	1				1	1							
Aim and fire M203 GL	41	17	1	1				1	1							
Identify support position to fire on enemy	40	17				1		1		1		1				1
Maintain position relative to other personnel	37	20	1		1						1		1	2		1
Read standard military symbols on a map	32	17	2	1	1		1					1			1	
Identify overwatch position	27	12				1		1								1
Identify areas that mask supporting element fires	26	15		1			2			1					1	
Perceive relative position of weapon fire	26	17				2	2		2							1
Change rate of fire	17	9														
Fire flare to signal	13	8														
Aim and fire LAW	12	6														
Identify obstacles	12	7														
Place crew served weapons in operation	12	11		1		1		1						1	1	
Identify dead space	12	8							1					1		
Identify light reflected from shiny objects	12	10	1													
Arm hand grenade	11	7														
Identify firing positions in urban area	11	3														
Aim, fire, and track DRAGON	10	5														
Discern location within an area	10	6														
Read dosimeter scale	10	6					1									
Set frequency on radio	10	6										1				
Identify glow from cigarette	9	9			1							1				
Hear own movement noise	8	5														
Read CEOIs	8	8			1		1					1				
Identify firing positions in building	7	4														
Identify orientation of soldier's weapon or fire	7	7														
Identify flashes from enemy weapons	7	7			1											

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem/Bio Decontamination	33 7-3/4-1065 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1027 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Give verbal orders	490	67	4	2	1	17	8	8	11	5	6	1
Use password	24	12		4								
Blow whistle for signal	13	8										
Call in preplanned fire requests	11	11										
Inspect for correct "soldier's load"	5	5					1					
Hear orders	442	66	4	2	1	16	7	6	10	5	4	1
Operate radio or telephone	89	41	1		2	7				3	1	[illegible]
Identify safe and danger area	68	32					2				1	
Perceive relative position of other units	63	29							1			
Give hand and arm signals	58	21		4	1				1			
Move in accordance with directions	50	22				1			3			
Visually search for enemy	50	27		1	2	1		2		4		
Identify hand and arm signals	47	17		2					1			
Aim and fire individual weapon	45	20	1									6
Aim and fire crew served weapon	43	19	1									6
Aim and fire M60 MG	43	17	1									6
Aim and fire M203 GL	41	17	1									6
Identify support position to fire on enemy	40	17		1								
Maintain position relative to other personnel	37	20					1				1	
Read standard military symbols on a map	32	17				1	2			1		
Identify overwatch position	27	12	1									
Identify areas that mask supporting element fires	26	15										
Perceive relative position of weapon fire	26	17									2	1
Change rate of fire	17	9	1								[illegible]	
Fire flare to signal	13	8										
Aim and fire LAW	12	6										
Identify obstacles	12	7		1	2							
Place crew served weapons in operation	12	11										
Identify dead space	12	8			1							
Identify light reflected from shiny objects	12	10					1	1	1			
Arm hand grenade	11	7										
Identify firing positions in urban area	11	3										
Aim, fire, and track DRAGON	10	5										
Discern location within an area	10	6				2						
Read dosimeter scale	10	6										
Set frequency on radio	10	6										
Identify glow from cigarette	9	9					1	1	1			
Hear own movement noise	8	5			1			1	1			
Read CEOIs	8	8			1							
Identify firing positions in building	7	4										
Identify orientation of soldier's weapon or fire	7	7										
Identify flashes from enemy weapons	7	7					1					1

Activity	Total Occurrences of Activity	# Tasks with this Activity	39 7-3/4-1048 Aerial Resupply	40 31-5-0073 Operate in NBC Environ.	41 7-3/4-1052 Cross Chem. Cont. Area	42 31-5-0070 Prepare for NBC Operations	43 7-3/4-1034 Cross Wire Obstacle	44 31-5-0103 Infiltrate Area by Land	45 7-3/4-1030 Clear Wood Line	46 7-3/4-1058 Sustain	47 31-5-0108 Estab. Mission Support Site	48 7-3/4-9013 React to Contact
Give verbal orders	490	67	5	2	5	13	2	7	6	13	3	4
Use password	24	12										
Blow whistle for signal	13	8										
Call in preplanned fire requests	11	11										
Inspect for correct "soldier's load"	5	5										
Hear orders	442	66	2	2	4	13	2	7	6	13	4	4
Operate radio or telephone	89	41		2	3	3			2	6	1	
Identify safe and danger area	68	32	2	1		2	1	2			3	
Perceive relative position of other units	63	29	1			1		2		1		1
Give hand and arm signals	58	21	5									
Move in accordance with directions	50	22		1	1			1	2			
Visually search for enemy	50	27			3		1		1	1	2	
Identify hand and arm signals	47	17										1
Aim and fire individual weapon	45	20						1				2
Aim and fire crew served weapon	43	19						1				2
Aim and fire M60 MG	43	17										
Aim and fire M203 GL	41	17										
Identify support position to fire on enemy	40	17					4					
Maintain position relative to other personnel	37	20		1	1		3					
Read standard military symbols on a map	32	17			1							
Identify overwatch position	27	12										
Identify areas that mask supporting element fires	26	15	1									
Perceive relative position of weapon fire	26	17			1							
Change rate of fire	17	9										
Fire flare to signal	13	8										
Aim and fire LAW	12	6										
Identify obstacles	12	7	3							1		
Place crew served weapons in operation	12	11										
Identify dead space	12	8							3			
Identify light reflected from shiny objects	12	10				1	1					
Arm hand grenade	11	7										
Identify firing positions in urban area	11	3										
Aim, fire, and track DRAGON	10	5										
Discern location within an area	10	6						2				
Read dosimeter scale	10	6		1								
Set frequency on radio	10	6										
Identify glow from cigarette	9	9				1						
Hear own movement noise	8	5										
Rec'd CEOIs	8	8		1							1	
Identify firing positions in building	7	4										
Identify orientation of soldier's weapon or fire	7	7										
Identify flashes from enemy weapons	7	7					1					1

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 31-5-0047 Employ Countermeasures	50 7-3/4-1057 Prepare for Combat	51 7-3/4-1077 Cross Nucl. Cont. Area	52 31-5-0121 Exfiltrate by Air	53 31-5-02029 Confirm Operation Plan	54 7-3/4-1050 Prepare for Chem. Attack	55 31-5-0075 Radiological Decontamination	56 31-5-0072 React to Nuclear Strike	57 7-3-1042 Reconnoiter Area	58 7-3/4-1033 Boat Movement
Give verbal orders	490	67	6	49	10	2	[illegible]	3	4	5	7	5
Use password	24	12										
Blow whistle for signal	13	8										
Call in preplanned fire requests	11	11										
Inspect for correct "soldier's load"	5	5		1			1					
Hear orders	442	66	6	17	10	2	7	3	4	5	2	2
Operate radio or telephone	89	41	1		3	2	1		1	2	1	
Identify safe and danger area	68	32									1	
Perceive relative position of other units	63	29		2				1				1
Give hand and arm signals	58	21										
Move in accordance with directions	50	22	1									1
Visually search for enemy	50	27	1		3	1		1	1			
Identify hand and arm signals	47	17										
Aim and fire individual weapon	45	20										
Aim and fire crew served weapon	43	19										
Aim and fire M60 MG	43	17										
Aim and fire M203 GL	41	17										
Identify support position to fire on enemy	40	17				3						
Maintain position relative to other personnel	37	30			2							
Read standard military symbols on a map	32	17		1	2		6					
Identify overwatch position	27	12										
Identify areas that mask supporting element fires	26	15									1	
Perceive relative position of weapon fire	26	17										
Change rate of fire	17	9										
Fire flare to signal	13	8										
Aim and fire LAW	12	6										
Identify obstacles	12	7										
Place crew served weapons in operation	12	11										
Identify dead space	12	8										
Identify light-reflected from shiny objects	12	10	1									
Arm hand grenade	11	7										
Identify firing positions in urban area	11	3										
Aim, fire, and track DRAGON	10	5										
Discern location within an area	10	6										
Read dosimeter scale	10	6						1	5	1		
Set frequency on radio	10	6										
Identify glow from cigarette	9	9	1									
Hear own movement noise	8	5										
Read CEOIs	8	8										
Identify firing positions in building	7	4										
Identify orientation of soldier's weapon or fire	7	7								1		1
Identify flashes from enemy weapons	7	7										

Activity	Total Occurrences of Activity	# Tasks with this Activity	59 7-3/4-9012 React to Nuclear Attack	60 7-3/4-1051 Prepare for Nuc. Attack	61 31-5-0005 Infiltrate by Air	62 7-3/4-9011 React to Chemical Attack	63 31-5-0071 React to Chem or Bio Attack	64 31-5-0113 Prepare for Exfiltration	65 31-5-0010 Conduct Assembly	66 31-5-3044 Control Info Dissemination	67 7-3/4-9003 React to Indirect Fire
Give verbal orders	490	67	3	3	5	3	4	1	1	4	3
Use password	24	12		1							
Blow whistle for signal	13	9									
Call in preplanned fire requests	11	11		1							
Inspect for correct "soldier's load"	5	5								1	
Hear orders	442	66	3	3	5	2	[illegible]	1	1	4	
Operate radio or telephone	[illegible]	41	1	1		1	2				
Identify safe and danger area	65	32									
Perceive relative position of other units	63	29			2			1			
Give hand and arm signals	58	21									
Move in accordance with directions	50	22			1						
Visually search for enemy	50	27	1								
Identify hand and arm signals	47	17				1					
Aim and fire individual weapon	45	20									
Aim and fire crew served weapon	43	19									
Aim and fire M60 MG	43	17									
Aim and fire M203 GL	41	17									
Identify support position to fire on enemy	40	17									
Maintain position relative to other personnel	[illegible]	20							1		
Read standard military symbols on a map	32	17									
Identify overwatch position	27	12									
Identify areas that mask supporting element fires	26	15									
Perceive relative position of weapon fire	[illegible]	17									
Change rate of fire	17	9									
Fire flare to signal	13	6									
Aim and fire LAW	12	6									
Identify obstacles	12	7									
Place crew served weapons in operation	12	11									
Identify dead space	12	8									
Identify light reflected from shiny objects	12	10									
Arm hand grenade	11	7									
Identify firing positions in urban area	11	3									
Aim, fire, and track DRAGON	10	5									
Discern location within an area	10	6									
Read dosimeter scale	10	6									
Set frequency on radio	10	6									
Identify glow from cigarette	9	9									
Hear own movement noise	8	5									
Read CEOIs	8	8									
Identify firing positions in building	7	4									
Identify orientation of soldier's weapon or fire	7	7	1								
Identify flashes from enemy weapons	7	7									

Activity	Total Occurrences of Activity	# Tasks with this Activity	1 7-3/4-1021 Defend	2 7-3/4-1018 Antiarmor Ambush	3 7-3/4-1037 Overwatch	4 7-3/4-1011 Assault	5 7-3/4-1020 Point Ambush	6 7-3/6-1019 Hasty Ambush	7 7-3/4-1025 Move Tactically	8 7-3/4-1012 Knock Out Bunker	9 7-3/4-1054 Clear Building	10 7-3/4-1044 Occupy Patrol Base	11 7-3/4-1015 Clear Trench Line	12 7-3/4-1008 Disengage	13 7-3/4-1028 Cross Danger Area	14 7-3/4-1014 Breach Obstacle
Engage aircraft with small arms	6	1														
Camouflage self (to include face)	5	5							1		1	1				
Fill rifle magazines	5	5			1						1					1
Walk fire across the objective	5	5			1		1			1	1					
Identify orientation of main guns on vehicles	4	4			1			1								1
Discern direction enemy is moving	4	4	1				1	1								
Place LAW in operation	4	4	1	1		1		1								
Prepare DRAGON sight	4	4	1	1		1		1								
Read watch to tell time	4	4						1								
Use night vision devices	4	3														
Determine azimuth and direction to distant object	3	3				1	1									
Identify orientation of soldier's body	3	3		1				1								
Shift fires	3	1				3										
Count/inventory expendable supplies	3	3														
Discern own movement direction	3	3							1					1		
Identify rear of armored vehicle	3	3	1	1												
Identify approach to LZ/DZ free of tall trees, etc.	2	2														
Identify distribution points for supplies	2	2														
Orient map to field of view	2	1														
Place weapons on safe	2	2										1				
Follow azimuth	2	2														
Identify armored vehicle blind spots	2	2		1				1								
Identify LZ	2	1														
Identify orientation of soldier's field of view	2	2		1				1								
Perceive relative position of lights	2	1														
Identify side of tank	2	2		1												
Identify slopes which must be climbed	2	2										1				
Identify steep slopes	2	2										1				
Use binoculars	2	2														
Use compass to determine azimuth readings	2	2														
Determine direction distant aircraft is flying	1	1														
Inspect boat landing	1	1														
Bend radio antenna down	1	1														
Identify blind side of bunker	1	1								1						
Identify bunker	1	1			1											
Test fire weapons	1	1														
Visually search for aircraft	1	1														
Count ammunition	1	1											1			
Identify tanks	1	1														
Mark vehicles	1	1														
Smell smoke from cigarettes	1	1														
Identify entrance to bunker																

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 7-3/4-1040 Passage of Lines	16 7-3/4-1060 Stay Behind	17 31-5-0110 Establish Surveillance Site	18 31-5-0204 Conduct Recovery Ops.	19 7-3/4-1064 Linkup	20 31-5-0203 Interdict a Target	21 7-3/4-1022 Occupy Assembly Area	22 7-3/4-1047 Consolidate & Reorganize	23 7-3/4-1036 Helicopter Movement	24 7-3/4-1057 Maintain Op. Security	25 31-5-0121 Exfiltrate by Land	26 7-3/4-1055 Defend Built-up Area	27 31-5-0107 Move in Denied Area	28 7-3/4-1041 Occupy Obj. Rally Pt.
Engage aircraft with small arms	6	1														
Camouflage self (to include face)	5	5										1				
Fill rifle magazines	5	5		1												
Walk fire across the objective	5	5														
Identify orientation of main guns on vehicles	4	4														
Discern direction enemy is moving	4	4														
Place LAW in operation	4	4														
Prepare DRAGON sight	4	4														
Read watch to tell time	4	4			1		1				1					
Use night vision devices	4	3			1							1				
Determine azimuth and direction to distant object	3	3														
Identify orientation of soldier's body	3	3									1					
Shift fires	3	1														
Count/inventory expendable supplies	3	3								1						
Discern own movement direction	3	3														
Identify rear of armored vehicle	3	3														
Identify approach to LZ/DZ free of tall trees, etc.	2	2													1	
Identify distribution points for supplies	2	2		1											1	
Orient map to field of view	2	1														
Place weapons on safe	2	2														
Follow azimuth	2	2														
Identify armored vehicle blind spots	2	2														
Identify LZ	2	1														
Identify orientation of soldier's field of view	2	2														
Perceive relative position of lights	2	1				2										
Identify side of tank	2	2														
Identify slopes which must be climbed	2	2														1
Identify steep slopes	2	2														1
Use binoculars	2	2			1											
Use compass to determine azimuth readings	2	2	1													
Determine direction distant aircraft is flying	1	1														
Inspect boat landing	1	1														
Bend radio antenna down	1	1									1					
Identify blind side of bunker	1	1														
Identify bunker	1	1														
Test fire weapons	1	1														
Visually search for aircraft	1	1														
Count ammunition	1	1														
Identify ranks	1	1								1						
Mark vehicles	1	1								1						
Smell smoke from cigarettes	1	1														
Identify entrance to bunker																

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem/Bio Decontamination	33 7-3/4-1065 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1027 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Engage aircraft with small arms	6	1									6	
Camouflage self (to include face)	5	5										
Fill rifle magazines	5	5										
Walk fire across the objective	5	5		1								
Identify orientation of main guns on vehicles	4	4										
Discern direction enemy is moving	4	4										
Place LAW in operation	4	4										
Prepare DRAGON sight	4	4										
Read watch to tell time	4	4										
Use night vision devices	4	3								2		
Determine azimuth and direction to distant object	3	3								1		
Identify orientation of soldier's body	3	3										
Shift fires	3	1										
Count/inventory expendable supplies	3	3										
Discern own movement direction	3	3										
Identify rear of armored vehicle	3	3				1						
Identify approach to LZ/DZ free of tall trees, etc.	2	2										
Identify distribution points for supplies	2	2										
Orient map to field of view	2	1								2		
Place weapons on safe	2	2										
Follow azimuth	2	2	1									
Identify armored vehicle blind spots	2	2										
Identify LZ	2	1										
Identify orientation of soldier's field of view	2	2										
Perceive relative position of lights	2	1										
Identify side of tank	2	2				1						
Identify slopes which must be climbed	2	2										
Identify steep slopes	2	2										
Use binoculars	2	2								1		
Use compass to determine azimuth readings	2	2						1				
Determine direction distant aircraft is flying	1	1									1	
Inspect boat landing	1	1						1				
Bend radio antenna down	1	1										
Identify blind side of bunker	1	1										
Identify bunker	1	1										
Test fire weapons	1	1										
Visually search for aircraft	1	1		1								
Count ammunition	1	1										
Identify tanks	1	1										
Mark vehicles	1	1										
Smell smoke from cigarettes	1	1						1				
Identify entrance to bunker												

Activity	Total Occurrences of Activity	# Tasks with this Activity	39	40	41	42	43	44	45	46	47	48
			7-3/4-1048	31-5-0073	7-3/4-1052	31-5-0070	7-3/4-1034	31-5-0103	7-3/4-1030	7-3/4-1058	31-5-0108	7-3/4-9013
			Aerial Resupply	Operate in NBC Environ.	Cross Chem. Cont. Area	Prepare for NBC Operations	Cross Water Obstacle	Infiltrate Area by Land	Clear Wood Line	Sustain	Estab. Mission Support Site	React to Contact
Engage aircraft with small arms	6	1										
Camouflage self (to include face)	5	5										
Fill rifle magazines	5	5								1		
Walk fire across the objective	5	5										
Identify orientation of main guns on vehicles	4	4							1			
Discern direction enemy is moving	4	4										
Place LAW in operation	4	4										
Prepare DRAGON sight	4	4										
Read watch to tell time	4	4										
Use night vision devices	4	3										
Determine azimuth and direction to distant object	3	3										
Identify orientation of soldier's body	3	3										
Shift fires	3	1										
Count/inventory expendable supplies	3	3				1						
Discern own movement direction	3	3							1			
Identify rear of armored vehicle	3	3										
Identify approach to LZ/DZ free of tall trees, etc.	2	2	1									
Identify distribution points for supplies	2	2										
Orient map to field of view	2	1										
Place weapons on safe	2	2									1	
Follow azimuth	2	2										
Identify armored vehicle blind spots	2	2										
Identify LZ	2	1										
Identify orientation of soldier's field of view	2	2										
Perceive relative position of lights	2	1										
Identify side of tank	2	2										
Identify slopes which must be climbed	2	2										
Identify steep slopes	2	2										
Use binoculars	2	2										
Use compass to determine azimuth readings	2	2										
Determine direction distant aircraft is flying	1	1										
Inspect boat landing	1	1										
Bend radio antenna down	1	1										
Identify blind side of bunker	1	1										
Identify bunker	1	1										
Test fire weapons	1	1										
Visually search for aircraft	1	1										
Count ammunition	1	1										
Identify ranks	1	1										
Mark vehicles	1	1										
Smell smoke from cigarettes	1	1										
Identify entrance to bunker												

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 31-5-0047 Employ Countermeasures	50 7-3/4-1057 Prepare for Combat	51 7-3/4-1077 Cross Nucl. Cont. Area	52 31-5-0123 Exfiltrate by Air	53 31-5-02020 Confirm Operation Plan	54 7-3/4-1050 Prepare for Chem. Attack	55 31-5-0075 Radiological Decontamination	56 31-5-0072 React to Nuclear Strike	57 7-3-1042 Reconnoiter Area	58 7-3/4-1033 Boat Movement
Engage aircraft with small arms	6	1										
Camouflage self (to include face)	5	5					1					
Fill rifle magazines	5	5										
Walk fire across the objective	5	5										
Identify orientation of main guns on vehicles	4	4										
Discern direction enemy is moving	4	4										
Place LAW in operation	4	4										
Prepare DRAGON sight	4	4										
Read watch to tell time	4	4										
Use night vision devices	4	3										
Determine azimuth and direction to distant object	3	3										
Identify orientation of soldier's body	3	3										
Shift fires	3	1										
Count/inventory expendable supplies	3	3						1				
Discern own movement direction	3	3										
Identify rear of armored vehicle	3	3										
Identify approach to LZ/DZ free of tall trees, etc.	2	2										
Identify distribution points for supplies	2	2										
Orient map to field of view	2	1										
Place weapons on safe	2	2										
Follow azimuth	2	2										
Identify armored vehicle blind spots	2	2										
Identify LZ	2	1				2						
Identify orientation of soldier's field of view	2	2										
Perceive relative position of lights	2	1										
Identify side of tank	2	2										
Identify slopes which must be climbed	2	2										
Identify steep slopes	2	2										
Use binoculars	2	2										
Use compass to determine azimuth readings	2	2										
Determine direction distant aircraft is flying	1	1										
Inspect boat loading	1	1										
Bend radio antenna down	1	1										
Identify blind side of bunker	1	1										
Identify bunker	1	1										
Test fire weapons	1	1		1								
Visually search for aircraft	1	1										
Count ammunition	1	1										
Identify ranks	1	1										
Mark vehicles	1	1										
Smell smoke from cigarettes	1	1										
Identify entrance to bunker												

Activity	Total Occurrences of Activity	# Tasks with this Activity	59 7-3/4-9012 React to Nuclear Attack	60 7-3/4-1051 Prepare for Nuc. Attack	61 31-5-0005 Infiltrate by Air	62 7-3/4-9011 React to Chemical Attack	63 31-5-0071 React to Chem or Bio Attack	64 31-5-0113 Prepare for Exfiltration	65 31-5-0010 Conduct Assembly	66 31-5-0044 Control Info Dissemination	67 7-3/4-9003 React to Indirect Fire
Engage aircraft with small arms	6	1									
Camouflage self (to include face)	5	5									
Fill rifle magazines	5	5									
Walk fire across the objective	5	3									
Identify orientation of main guns on vehicles	4	4									
Discern direction enemy is moving	4	4									
Place LAW in operation	4	4									
Prepare DRAGON sight	4	4									
Read watch to tell time	4	4									
Use night vision devices	4	3									
Determine azimuth and direction to distant object	3	3									
Identify orientation of soldier's body	3	3									
Shift fires	3	1									
Count/inventory expendable supplies	3	3									
Discern own movement direction	3	3									
Identify rear of armored vehicle	3	3									
Identify approach to LZ/DZ free of tall trees, etc.	2	2									
Identify distribution points for supplies	2	2									
Orient map to field of view	2	1									
Place weapons on safe	2	2									
Follow azimuth	2	2									1
Identify armored vehicle blind spots	2	2									
Identify LZ	2	1									
Identify orientation of soldier's field of view	2	2									
Perceive relative position of lights	2	1									
Identify side of tank	2	2									
Identify slopes which must be climbed	2	2									
Identify steep slopes	2	2									
Use binoculars	2	2									
Use compass to determine azimuth readings	2	2									
Determine direction distant aircraft is flying	1	1									
Inspect boat landing	1	1									
Bend radio antenna down	1	1									
Identify blind side of bunker	1	1									
Identify bunker	1	1									
Test fire weapons	1	1									
Visually search for aircraft	1	1									
Count ammunition	1	1									
Identify tanks	1	1									
Mark vehicles	1	1									
Smell smoke from cigarettes	1	1									
Identify entrance to bunker											

			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			7-3/4-1021	7-3/4-1018	7-3/4-1007	7-3/4-1011	7-3/4-1020	7-3/4-1019	7-3/4-1025	7-3/4-1012	7-3/4-1054	7-3/4-1044	7-3/4-1015	7-3/4-1008	7-3/4-1028	7-3/4-1014
Activity	Total Occurrences of Activity	# Tasks with this Activity	Defend	Antiarmor Ambush	Overwatch	Assault	Point Ambush	Hasty Ambush	Move Tactically	Knock Out Bunker	Clear Building	Occupy Patrol Base	Clear Trench Line	Disengage	Cross Danger Area	Breach Obstacle
Steer a boat																
Identify bushes																
Move upright, tactically	79	36	3		1	3	1		2	1		2	7	1	2	7
Identify covered and concealed route	77	33	10	4	2	5		1	8	1	1	1	2	2	2	5
Identify actual squad members	70	35	2		3	2	4	3	1			1	2	2	1	2
Move upright, reconnoiter	52	22	6	5			2	2		1		2			1	1
Identify assigned sectors	49	21	6	2	1	1	2		5		1	2	1		2	6
Inspect Equipment	42	22										1				
Distribute supplies and equipment	38	18											2			
Estimate distance from self to a distant point	35	19		1					10			1		1	1	
Read charts and diagrams	34	19	5					1	1			1				
Move by rush	32	16				7	1	1		1	2		2	2	2	
Identify enemy soldiers	29	15	6		2	2	2	1				1				
Record observation notes	28	13										1		1		
Operate chemical-alarm	26	10														
Identify restricted fire lines, check points, etc.	26	17	1	1	1	1						3		1		
Move with stealth	26	11	2													
Identify activity of personnel	25	16	1		3	2	2	1							1	
Check radio instruments	25	8														
Read written order	25	11														
Identify actual chain of command	23	16					3		1				1	1		
Administer first aid	19	13					1					1				1
Carry protective mask	19	11														2
Position/sight weapons	16	9	3									1	2		2	2
Move upright rapidly, tactically	1ʋ	9				5			1				1			3
Prepare demolitions	14	8	2				2									2
Count members of the squad	12	9			2	1	1	1					1	1	1	
Follow route designated on map	11	8					1							1		
Identify civilians	11	9	1				1					1				
Identify enemy voices	11	11			1					1	1	1				
Throw smoke grenade	10	8	1			2		1		1	1					1
Set up early warning (trip wire) devices	9	8	1									2				
Attach telephone to commo wire	9	7	3		1					1		1				
Dismount vehicle	9	7	1			1		1			1					2
Move upright in built-up area, tactically	9	2							6		3					
Operate flashlight	9	5							1							
Set up and employ Claymore mines	9	7	3	1			1									
Identify firing positions in natural terrain	8	4	2		4	1										
Identify squad voices	8	5			1							1				
Mark routes	8	5														1
Discuss map coordinates for indirect fire	7	6	1	2		1	1	1								1
Enter and exit rubber boat	7	5									1					

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 7-3/4-1040 Passage of Lines	16 7-3/4-1060 Stay Behind	17 31-5-0110 Establish Surveillance Site	18 31-5-0204 Conduct Recovery Ops	19 7-3/4-1064 Linkup	20 31-5-0203 Interdict a Target	21 7-3/4-1022 Occupy Assembly Area	22 7-3/4-1047 Consolidate & Reorganize	23 7-3/4-1036 Helicopter Movement	24 7-3/4-1057 Maintain Op. Security	25 31-5-0121 Exfiltrate by Land	26 7-3/4-1055 Defend Built-up Area	27 31-5-0107 Move in Denied Area	28 7-3/4-1041 Occupy Obj. Rally Pt.
Steer a boat																
Identify bushes																
Move upright, tactically	79	36	2	3	1	2	4	4	3		1	1			2	
Identify covered and concealed route	77	33	1	2	1	1	2	1		1	1				1	1
Identify actual squad members	70	35	4	1		2		2	1	2			3			2
Move upright, reconnoiter	52	22		3	1	4		3					5	1		
Identify assigned sectors	49	21				2		2	3	2				5		2
Inspect Equipment	42	22				1		2			3	2	1		1	
Distribute supplies and equipment	38	18		2	1	1				1	1			1		
Estimate distance from self to a distant point	35	19			3			2			1					2
Read charts and diagrams	34	19		1	1		1					1		1		
Move by rush	32	16	1			1										
Identify enemy soldiers	29	15				2			1	2	1					
Record observation notes	28	13	1	1		1		1					1			
Operate chemical-alarm	26	10														
Identify restricted fire lines, check points, etc.	26	17			1	3		3					2	2	1	
Move with stealth	26	11		2		4							1		2	
Identify activity of personnel	25	16													1	
Check radio instruments	25	8														
Read written order	25	11			1		1					1				
Identify actual chain of command	21	16	1			1		1		1				1		
Administer first aid	19	13				1				2						
Carry protective mask	19	11								1						
Position/sight weapons	16	9					1							3		1
Move upright rapidly, tactically	16	9										1		1		
Prepare demolitions	14	8		1				1	1					1		
Count members of the squad	12	9	3													
Follow route designated on map	11	8														
Identify civilians	11	9							1			1				
Identify enemy voices	11	11	1												1	
Throw smoke grenade	10	8														
Set up early warning (trip wire) devices	9	8				1		1						1	1	
Attach telephone to commo wire	9	7							1					1	1	
Dismount vehicle	9	7														
Move upright in built-up area, tactically	9	2														
Operate flashlight	9	5	3	1			3					1				
Set up and employ Claymore mines	9	7						1						1	1	
Identify firing positions in natural terrain	8	4														1
Identify squad voices	8	5	1													
Mark routes	8	5	1											4		
Discuss map coordinates for indirect fire	7	6														
Enter and exit rubber boat	7	5														

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem/Bio Decontamination	33 7-3/4-1055 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1022 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Steer a boat												
Identify bushes												
Move upright, tactically	79	36		3		1	2				1	
Identify covered and concealed route	77	33					2					
Identify actual squad members	70	35		2		4	1	4				
Move upright, reconnoiter	52	22		3			1					
Identify assigned sectors	49	21	1	1								
Inspect Equipment	42	22				1			1		1	
Distribute supplies and equipment	38	18				2		1				
Estimate distance from self to a distant point	35	19	1							1		
Read charts and diagrams	34	19				2	2					
Move by rush	32	16	4								1	3
Identify enemy soldiers	29	15								2		
Record observation notes	28	13					2					
Operate chemical-alarm	26	10				6						
Identify restricted fire lines, check points, etc.	26	17	1									
Move with stealth	26	11					7			1		
Identify activity of personnel	25	16						5	1			
Check radio instruments	25	8				1						
Read written order	25	11				2			1			
Identify actual chain of command	21	16										
Administer first aid	19	13				2						
Carry protective mask	19	11				3						
Position/sight weapons	16	9										
Move upright rapidly, tactically	16	9	2									
Prepare demolitions	14	8										
Count members of the squad	12	9	1									
Follow route designated on map	11	8				2						
Identify civilians	11	9								2		
Identify enemy voices	11	11		1			1					
Throw smoke grenade	10	8	1									2
Set up early warning (trip wire) devices	9	8										
Attach telephone to commo wire	9	7										
Dismount vehicle	9	7									1	
Move upright in built-up area, tactically	9	2										
Operate flashlight	9	5										
Set up and employ Claymore mines	9	7										
Identify firing positions in natural terrain	8	4										
Identify squad voices	8	5		4								
Mark routes	8	5		1								
Discern map coordinates for indirect fire	7	6										
Enter and exit rubber boat	7	5						1	1			

Activity	Total Occurrences of Activity	# Tasks with this Activity	39 7-3/4-1048 Aerial Resupply	40 31-5-0073 Operate in NBC Environ.	41 7-3/4-1052 Cross Chem. Cont. Area	42 31-5-0070 Prepare for NBC Operations	43 7-3/4-1034 Cross Water Obstacle	44 31-5-0103 Infiltrate Area by Land	45 7-3/4-1030 Clear Wood Line	46 7-3/4-1058 Sustain	47 31-5-0108 Estab. Mission Support Site	48 7-3/4-3013 React to Contact
Steer a boat												
Identify bushes												
Move upright, tactically	79	36	1		2		3	2	1		1	
Identify covered and concealed route	77	33	2				1	1	1	2	3	1
Identify actual squad members	70	35					2			2		2
Move upright, reconnoiter	52	22	1					2	1		2	
Identify assigned sectors	49	21	1									
Inspect Equipment	47	22			2	2	1	1		4		
Distribute supplies and equipment	38	18	5			3				7		
Estimate distance from self to a distant point	35	19	1		2				2	1	1	
Read charts and diagrams	34	19		2	1	2					1	
Move by rush	32	16										1
Identify enemy soldiers	29	15	2									
Record observation notes	28	13		1	1	1						
Operate chemical-alarm	26	10		4	2	4						
Identify restricted fire lines, check points, etc.	26	17		1				1				
Move with stealth	26	11						1				
Identify activity of personnel	25	16						1			1	
Check radio instruments	25	8		4		4						
Read written order	25	11		2		1						
Identify actual chain of command	21	16		1						1		3
Administer first aid	19	13		1	1					4		
Carry protective mask	19	11		2		3	1					
Position/sight weapons	16	9							1			
Move upright rapidly, tactically	16	9					1		1			
Prepare demolitions	14	8									2	
Count members of the squad	12	9										
Follow route designated on map	11	8			2							
Identify civilians	11	9	1									
Identify enemy voices	11	11					1					
Throw smoke grenade	10	8										
Set up early warning (trip wire) devices	9	8	1			1						
Attach telephone to commo wire	9	7										
Dismount vehicle	9	7							2			
Move upright in built-up area, tactically	9	2										
Operate flashlight	9	5										
Set up and employ Claymore mines	9	7	1									
Identify firing positions in natural terrain	8	4										
Identify squad voices	8	5					1					
Mark routes	8	5										
Discern map coordinates for indirect fire	7	6										
Enter and exit rubber boat	7	5					2					

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 31-5-0047 Employ Countermeasures	50 7-3/4-1057 Prepare for Combat	51 7-3/4-1027 Cross Nucl. Cont. Area	52 31-5-0123 Exfiltrate by Air	53 31-5-02020 Confirm Operation Plan	54 7-3/4-1050 Prepare for Chem. Attack	55 31-5-0075 Radiological Decontamination	56 31-5-0072 React to Nuclear Strike	57 7-3-1042 Reconnoiter Area	58 7-3/4-1033 Boat Movement
Steer a boat												
Identify bushes												
Move upright, tactically	79	36		3	2		2		1			
Identify covered and concealed route	77	33									1	
Identify actual squad members	70	35		3			1		1	1	1	2
Move upright, reconnoiter	52	22				1					4	
Identify assigned sectors	49	21		1								
Inspect Equipment	42	22	1	6	1							2
Distribute supplies and equipment	38	18		1			2			1		
Estimate distance from self to a distant point	35	19			1						1	
Read charts and diagrams	34	19		2	2		6		1			
Move by rush	32	16										
Identify enemy soldiers	29	15		2							2	1
Record observation notes	28	13		13					3			
Operate chemical-alarm	26	10			1			3		2		
Identify restricted fire lines, check points, etc.	26	17		1								
Move with stealth	26	11				1					1	
Identify activity of personnel	25	16	2			1			1	1		
Check radio instruments	25	8			6				6	2		
Read written order	25	11		8			6		1			
Identify actual chain of command	21	16								1	2	
Administer first aid	19	13			1							
Carry protective mask	19	11						1	1	1		
Position/sight weapons	16	9										
Move upright rapidly, tactically	16	9										
Prepare demolitions	14	8										
Count members of the squad	12	9										
Follow route designated on map	11	8			1					2		
Identify civilians	11	9									2	1
Identify enemy voices	11	11	1									
Throw smoke grenade	10	8										
Set up early warning (trip wire) devices	9	8										
Attach telephone to commo wire	9	7										
Dismount vehicle	9	7										
Move upright in built-up area, tactically	9	2										
Operate flashlight	9	5										
Set up and employ Claymore mines	9	7										
Identify firing positions in natural terrain	8	4										
Identify squad voices	6	5										
Mark routes	8	5							1			
Discern map coordinates for indirect fire	7	6										
Enter and exit rubber boat	7	5										2

Activity	Total Occurrences of Activity	# Tasks with this Activity	59 7-3/4-9012 React to Nuclear Attack	60 7-3/4-1051 Prepare for Nuc. Attack	61 31-5-0005 Infiltrate by Air	62 7-3/4-9011 React to Chemical Attack	63 31-5-0071 React to Chem or Bio Attack	64 31-5-0713 Prepare for Exfiltration	65 31-5-0010 Conduct Assembly	66 31-5-0044 Control Info Dissemination	67 7-3/4-9003 React to Indirect Fire
Steer a boat											
Identify bushes											
Move upright, tactically	79	36							1		
Identify covered and concealed route	77	33									1
Identify actual squad members	70	35			2	1	1				
Move upright, reconnoiter	52	22									
Identify assigned sectors	49	21									
Inspect Equipment	42	22		4	3					1	
Distribute supplies and equipment	38	18		1			5	1			
Estimate distance from self to a distant point	35	19									2
Read charts and diagrams	34	19									
Move by rush	32	16	1								2
Identify enemy soldiers	29	15									
Record observation notes	28	13									
Operate chemical-alarm	26	10	1			1	2				
Identify restricted fire lines, check points, etc.	26	17			2						
Move with stealth	26	11									
Identify activity of personnel	23	16			1						
Check radio instruments	25	8	1				2				
Read written order	25	11			1						
Identify actual chain of command	21	16	1				1				
Administer first aid	19	13	2			1	1				
Carry protective mask	19	11				1	3				
Position/sight weapons	16	9									
Move upright rapidly, tactically	16	9									
Prepare demolitions	14	8									
Count members of the squad	12	9									
Follow route designated on map	11	8			1		1				
Identify civilians	11	9									
Identify enemy voices	11	11						1			
Throw smoke grenade	10	8									
Set up early warning (trip wire) devices	9	8									
Attach telephone to commo wire	9	7									
Dismount vehicle	9	7									
Move upright in built-up area, tactically	9	2									
Operate flashlight	9	5									
Set up and employ Claymore mines	9	7									
Identify firing positions in natural terrain	8	4									
Identify squad voices	8	[illegible]									
Mark routes	8	5									
Discern map coordinates for indirect fire	7	6									
Enter and exit rubber boat	7	5									

Activity	Total Occurrences of Activity	# Tasks with this Activity	1 7-3/4-1021 Defend	2 7-3/4-1018 Antiarmor Ambush	3 7-3/4-1037 Overwatch	4 7-3/4-1011 Assault	5 7-3/4-1020 Point Ambush	6 7-3/4-1019 Hasty Ambush	7 7-3/4-1025 Move Tactically	8 7-3/4-1012 Knock Out Bunker	9 7-3/4-1054 Clear Building	10 7-3/4-1044 Occupy Patrol Base	11 7-3/4-1015 Clear Trench Line	12 7-3/4-1005 Disengage	13 7-3/4-1028 Cross Danger Area	14 7-3/4-1014 Breach Obstacle
Cook off grenade	6	3								1	2		3			
Throw "cooked off" grenade	6	3								1	2		3			
Identify damage to equipment	6	6		1												
Throw grenade	6	6	1			1				1						
Determine own location on map with control measures	5	4				1	1		1							
Lay, sight, and arm Claymore mine	5	4	1	2			1									
Repair equipment	5	3										2				
Enter trench	5	5									1		1			
Exit from aircraft	5	3									1					
Kill a soldier with a weapon	5	2		1		4										
Avoid kicking up dust	5	5	1			1								1		
Mark LZ/DZ	5	3														
Read Unit SOP	5	5														
Record dosimeter readings	5	3														
Write report on equipment status	5	5												1		
Discriminate between friendly and enemy aircraft	4	4														
Climb on and enter vehicle	4	4		1							1					
Enter and sit down in aircraft	4	4									1					
Enter door, window, hole	4	3								1	2					
Position chemical alarms	3	2	2													
Throw grenade through entrance to bunker	3	2								2			1			
Destroy equipment	3	2		2												
Estimate distance between two remote points	3	3												1		
Activate early warning (trip wire) devices	3	2	1													
Clear obstacles	3	3											1			
Mark cleared bunker or trench	3	2								1			2			
Move by low crawl	3	3												1		
Read markings on vehicles	3	3		1				1								
Set up tug line (Trip Wire)	3	3	1	1												
Use switchboard	3	3	1		1											
Write an NBC report	3	2														
Write report on personnel strength	3	3												1		
Move through a building with security of its front	2	2							1		1					
Feel for pressure probes and trip wires	2	1														2
Measure percent slope	2	2														
Crawl	2	1														
Cut slack trip wires	2	2		1												1
Draw sector sketch	2	2														
Identify slopes with difficult climb	2	2										1				
Identify slopes which cannot be climbed	2	2										1				
Mark cleared room	2	2							1		1					
Mark lanes through minefield	2	2							1							1

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 Passage of Lines 7-3/4-1040	16 Stay Behind 7-3/4-1060	17 Establish Surveillance Site 31-5-0110	18 Conduct Recovery Ops. 31-5-0204	19 Linkup 7-3/4-1064	20 Interdict a Target 31-5-0203	21 Occupy Assembly Area 7-3/4-1022	22 Consolidate & Reorganize 7-3/4-1047	23 Helicopter Movement 7-3/4-1036	24 Maintain Op. Security 7-3/4-1057	25 Exfiltrate by Land 31-5-0121	26 Defend Built-up Area 7-3/4-1055	27 Move in Denied Area 31-5-0107	28 Occupy Obj. Rally Pt. 7-3/4-1041
Cook off grenade	6	3														
Throw "cooked off" grenade	6	3														
Identify damage to equipment	6	6		1											1	
Throw grenade	6	6										1				
Determine own location on map with control measures	5	4														
Lay, sight, and arm Claymore mine	5	4							1							
Repair equipment	5	3														
Enter trench	5	5														
Exit from aircraft	5	3									1					
Kill a soldier with a weapon	5	2														
Avoid kicking up dust	5	5														
Mark LZ/DZ	5	3								1						
Read Unit SOP	5	5	1		1		1									
Record dosimeter readings	5	3														
Write report on equipment status	5	5												1		
Discriminate between friendly and enemy aircraft	4	4									1					
Climb on and enter vehicle	4	4														
Enter and sit down in aircraft	4	4									1					
Enter door, window, hole	4	3														
Position chemical alarm	3	2												1		
Throw grenade through entrance to bunker	3	2														
Destroy equipment	3	2		1												
Estimate distances between two remote points	3	3														
Activate early warning (trip wire) devices	3	2							2							
Clear obstacles	3	3														
Mark cleared bunker or trench	3	2														
Move by low crawl	3	3														
Read markings on vehicles	3	3					1									
Set up tug line (Trip Wire)	3	3							1							
Use switchboard	3	3												1		
Write an NBC report	3	2														
Write report on personnel strength	3	3												1		
Move through a building with sensing of its front	2	2														
Feel for pressure probes and trip wires	2	1														
Measure percent slope	2	2														1
Crawl	2	1														
Cut slack trip wires	2	2														
Draw sector sketch	2	2							1		1					
Identify slopes with difficult climb	2	2														1
Identify slopes which cannot be climbed	2	2														1
Mark cleared room	2	2														
Mark lanes through minefield	2	2														

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem/Bio Decontamination	33 7-3/4-1065 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1027 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Cook off grenade	6	3										
Throw "cooked off" grenade	6	3										
Identify damage to equipment	6	6				1						
Throw grenade	6	6	1									1
Determine own location on map with control measures	5	4										
Lay, sight, and arm Claymore mine	5	4										
Repair equipment	5	3										
Enter trench	5	5										
Exit from aircraft	5	3										
Kill a soldier with a weapon	5	2										
Avoid kicking up dust	5	5										
Mark LZ/DZ	5	3										
Read Unit SOP	5	5						1				
Record dosimeter readings	5	3										
Write report on equipment status	5	5										
Discriminate between friendly and enemy aircraft	4	4				1				1	1	
Climb on and enter vehicle	4	4										
Enter and sit down in aircraft	4	4										
Enter door, window, hole	4	3										
Position chemical alarm	3	2										
Throw grenade thru entrance to bunker	3	2										
Destroy equipment	3	2										
Estimate distances between two remote points	3	3				1			1			
Activate early warning (trip wire) devices	3	2										
Clear obstacles	3	3										
Mark cleared bunker or trench	3	2										
Move by low crawl	3	3										1
Read markings on vehicles	3	3										
Set up tug line (Trip Wire)	3	3										
Use switchboard	3	3										
Write an NBC report	3	2										
Write report on personnel strength	3	3										
Move through a building with sensing of its front	2	2										
Feel for pressure probes and trip wires	2	1										
Measure percent slope	2	2										
Crawl	2	1										
Cut slack trip wires	2	2										
Draw sector sketch	2	2										
Identify slopes with difficult climb	2	2										
Identify slopes which cannot be climbed	2	2										
Mark cleared room	2	2										
Mark lanes through minefield	2	2										

Activity	Total Occurrences of Activity	# Tasks with this Activity	39 7-3/4-1048 Aerial Resupply	40 31-5-0073 Operate in NBC Environ.	41 7-3/4-1052 Cross Chem. Cont. Area	42 31-5-0070 Prepare for NBC Operations	43 7-3/4-1034 Cross Water Obstacle	44 31-5-0103 Infiltrate Area by Land	45 7-3/4-1030 Clear Wood Line	46 7-3/4-1058 Sustain	47 31-5-0108 Estab. Mission Support Site	48 7-3/4-4013 React to Contact
Cook off grenade	6	3										
Throw "cooked off" grenade	6	3										
Identify damage to equipment	6	6										
Throw grenade	6	6										
Determine own location on map with control measures	5	4		2								
Lay, sight, and arm Claymore mine	5	4										
Repair equipment	5	3								2		
Enter trench	5	5										
Exit from aircraft	5	3										
Kill a soldier with a weapon	5	2										
Avoid kicking up dust	5	5		1								
Mark LZ/DZ	5	3	2									
Read Unit SOP	5	5		1								
Record dosimeter readings	5	3		1								
Write report on equipment status	5	5										
Discriminate between friendly and enemy aircraft	4	4										
Climb on and enter vehicle	4	4										
Enter and sit down in aircraft	4	4										
Enter door, window, hole	4	3										
Position chemical alarm	3	2										
Throw grenade through entrance to bunker	3	2										
Destroy equipment	3	2										
Estimate dist... between two remote points	3	3										
Ac... running (trip wire) devices	3	2										
[illegible]	3	3	1								1	
... or trench	3	2										
[illegible]	3	3										
... vehicles	3	3										
... (Trip Wire)	3	3										
U...	3	3										
Write ... report	3	2										
Write report on personnel strength	3	3										
Move through a building with sensing of its front	[illegible]	2										
Feel for pressure probes and trip wires	2	1										
Measure percent slope	2	2	1									
Crawl	2	1										
Cut slack trip wires	2	2										
Draw sector sketch	2	2										
Identify slopes with difficult climb	2	2										
Identify slopes which cannot be climbed	2	2										
Mark cleared room	2	2										
Mark lanes through minefield	2	2										

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 Employ Countermeasures 31-5-0047	50 Prepare for Combat 7-3/4-1957	51 Cross Nucl. Cont. Area 7-3/4-1077	52 Exfiltrate by Air 31-5-0123	53 Confirm Operat n Plan 31-5-02020
Cook off grenade	6	3					
Throw "cooked off" grenade	6	3					
Identify damage to equipment	6	6					
Throw grenade	6	6					
Determine own location on map with control measures	5	4					
Lay, sight, and arm Claymore mine	5	4					
Repair equipment	5	3					1
Enter trench	5	5					
Exit from aircraft	5	3					
Kill a soldier with a weapon	5	2					
Avoid kicking up dust	5	5			1		
Mark LZ/DZ	5	3				2	
Read Unit SOP	5	5					
Record dosimeter readings	5	3			2		
Write report on equipment status	5	5		1		1	
Discriminate between friendly and enemy aircraft	4	4					
Climb on and enter vehicle	4	4		1			
Enter and sit down in aircraft	4	4				1	
Enter door, window, hole	4	3					
Position chemical alarm	3	2					
Throw grenade through entrance to bunker	3	2					
Destroy equipment	3	2					
Estimate distances between two remote points	3	3					
Activate early warning (trip wire) devices	3	2					
Clear obstacles	3	3					
Mark cleared bunker or trench	3	2					
Move by low crawl	3	3					
Read markings on vehicles	3	3					
Set up tug line (Trip Wire)	3	3					
Use switchboard	3	3					
Write an NBC report	3	2			2		
Write report on personnel strength	3	3					
Move through a building with sensing of its front	2	2					
Feel for pressure probes and trip wires	2	1					
Measure percent slope	2	2					
Crawl	2	1					
Cut slack trip wires	2	2					
Draw sector sketch	2	2					
Identify slopes with difficult climb	2	2					
Identify slopes which cannot be climbed	2	2					
Mark cleared room	2	2					
Mark lanes through minefield	2	2					

Activity	54 Prepare for Chem. Attack 7-3/4-1050	55 Radiological Decontamination 31-5-0075	56 React to Nuclear Strike 31-5-0072	57 Reconnoiter Area 7-3-1042	58 Boat Movement 7-3/4-1033
Cook off grenade					
Throw "cooked off" grenade					
Identify damage to equipment		1			1
Throw grenade					
Determine own location on map with control measures					
Lay, sight, and arm Claymore mine					
Repair equipment					
Enter trench					
Exit from aircraft					
Kill a soldier with a weapon					
Avoid kicking up dust					
Mark LZ/DZ					
Read Unit SOP					
Record dosimeter readings		2			
Write report on equipment status		1			
Discriminate between friendly and enemy aircraft					
Climb on and enter vehicle					
Enter and sit down in aircraft					
Enter door, window, hole					
Position chemical alarm					
Throw grenade through entrance to bunker					
Destroy equipment					
Estimate distances between two remote points					
Activate early warning (trip wire) devices					
Clear obstacles					
Mark cleared bunker or trench					
Move by low crawl			1		
Read markings on vehicles					
Set up tug line (Trip Wire)					
Use switchboard					
Write an NBC report		1			
Write report on personnel strength		1			
Move through a building with sensing of its front					
Feel for pressure probes and trip wires					
Measure percent slope					
Crawl					
Cut slack trip wires					
Draw sector sketch					
Identify slopes with difficult climb					
Identify slopes which cannot be climbed					
Mark cleared room					
Mark lanes through minefield					

Activity	Total Occurrences of Activity	# Tasks with this Activity	59 7-3/4-9012 React to Nuclear Attack	60 7-3/4-1051 Prepare for Nuc. Attack	61 31-5-9005 Infiltrate by Air	62 7-3/4-9011 React to Chemical Attack	63 31-5-0071 React to Chem or Bio Attack	64 31-5-0113 Prepare for Exfiltration	65 31-5-0019 Conduct Assembly	66 31-5-0044 Control Info Dissemination	67 7-3/4-9003 React to Indirect Fire
Cook off grenade	6	3									
Throw "cooked off" grenade	6	3									
Identify damage to equipment	6	6									
Throw grenade	6	6									
Determine own location on map with control measures	5	4									
Lay, sight, and arm Claymore mine	5	4									
Repair equipment	5	3									
Enter trench	5	5	1	1							1
Exit from aircraft	5	3			3						
Kill a soldier with a weapon	5	2									
Avoid kicking up dust	5	5									
Mark LZ/DZ	5	3									
Read Unit SOP	5	5									
Record dosimeter readings	5	3									
Write report on equipment status	5	5									
Discriminate between friendly and enemy aircraft	4	4									
Climb on and enter vehicle	4	4		1							
Enter and sit down in aircraft	4	4			1						
Enter door, window, hole	4	3		1							
Position chemical alarm	3	2									
Throw grenade through entrance to bunker	3	2									
Destroy equipment	3	2									
Estimate distances between two remote points	3	3									
Activate early warning (trip wire) devices	3	2									
Clear obstacles	3	3									
Mark cleared bunker or trench	3	2									
Move by low crawl	3	3									
Read markings on vehicles	3	3									
Set up tug line (Trip Wire)	3	3									
Use switchboard	3	3									
Write an NBC report	3	2									
Write report on personnel strength	3	3									
Move through a building with securing of its front	2	2									
Feel for pressure probes and trip wires	2	1									
Measure percent slope	2	2									
Crawl	2	1									
Cut slack trip wires	2	2									
Draw sector sketch	2	2									
Identify slopes with difficult climb	2	2									
Identify slopes which cannot be climbed	2	2									
Mark cleared room	2	2									
Mark lanes through minefield	2	2									

Activity	Total Occurrences of Activity	# Tasks with this Activity	1 7-3/4-1021 Defend	2 7-3/4-1018 Antiarmor Ambush	3 7-3/4-1007 Overwatch	4 7-3/4-1011 Assault	5 7-3/4-1020 Point Ambush	6 7-3/4-1019 Hasty Ambush	7 7-3/4-1025 Move Tactically	8 7-3/4-1012 Knock Out Bunker	9 7-3/4-1054 Clear Building	10 7-3/4-1044 Occupy Patrol Base	11 7-3/4-1015 Clear Trench Line	12 7-3/4-1008 Disengage	13 7-3/4-1028 Cross Danger Area	14 7-3/4-1014 Breach Obstacle
Mark mine	2	2							1							1
Move bent over (when approaching helicopters)	2	2														
Place filters on flashlight	2	2														
Write report on supply status	2	2														
Check proper wearing of protective suit	1	1														
Employ probes (for mines)	1	1														1
Identify jet aircraft	1	1														
Inspect boats	1	1														
Position antitank mines	1	1														
Draw charts and diagrams	1	1														
Draw range card	1	1														
Enter bunker through rear entrance	1	1									1					
Guide squad and squad members	1	1												1		
Hang camouflage net	1	1														
Identify boat obstacles or hazards	1	1														
Identify shadows	1	1														
Move during limited visibility	1	1														
Use tug line	1	1		1												
Assemble crossing equipment (ropes & ponchos)	1	1														
Discern own rate of movement	1	1														
Draw control features on map	1	1														
Identify overhanging branches	1	1														
Identify puddles	1	1														
Mark taut trip wire	1	1														1
Mark weapon position	1	1														
Move by high crawl	1	1												1		
Sit in vehicle	1	1									1					
Inspect condition of feet	1	1										1				
Determine location of flying aircraft																
Estimate distance to flying aircraft																
Lay wire along final protective fire line																
Determine if rivers and streams are fordable																
Identify hand and arm signals with night vision devices																
Secure boat																
Burn garbage and waste																
Calculate distance moved (pacing and offsets)																
Conduct NBC surveys																
Identify a stroke (paddling rate)																
Use NBC equipment to conduct surveys																
Feel tug on tug line																
Identify a sleeping soldier																
Identify trash on the ground																

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 7-3/4-1040 Passage of Lines	16 7-3/4-1060 Stay Behind	17 31-5-0110 Establish Surveillance Site	18 31-5-0204 Conduct Recovery Ops.	19 7-3/4-1064 Linkup	20 31-5-0203 Interdict a Target	21 7-3/4-1022 Occupy Assembly Area	22 7-3/4-1047 Consolidate & Reorganize	23 7-3/4-1036 Helicopter Movement	24 7-3/4-1057 Maintain Op. Security	25 31-5-0121 Exfiltrate by Land	26 7-3/4-1055 Defend Built-up Area	27 31-5-0107 Move in Denied Area	28 7-3/4-1041 Occupy Obj. Rally Pt.
Mark mine	2	2														
Move bent over (when approaching helicopters)	2	2									1					
Place filters on flashlight	2	2										1				
Write report on supply status	2	2														
Check proper wearing of protective suit	1	1														
Employ probes (for mines)	1	1														
Identify jet aircraft	1	1														
Inspect boats	1	1														
Position antitank mines	1	1												1		
Draw charts and diagrams	1	1									1					
Draw range card	1	1									1					
Enter bunker through rear entrance	1	1														
Guide squad and squad members	1	1														
Hang camouflage set	1	1												1		
Identify boat obstacles or hazards	1	1														
Identify shadows	1	1										1				
Move during limited visibility	1	1	1													
Use tug line	1	1														
Assemble crossing equipmt. (ropes & ponchos)	1	1														
Discern own rate of movement	1	1													1	
Draw control features on map	1	1									1					
Identify overhanging branches	1	1														
Identify puddles	1	1														
Mark taut trip wire	1	1														
Mark weapon position	1	1						1								
Move by high crawl	1	1														
Sit in vehicle	1	1														
Inspect condition of feet	1	1														
Determine location of flying aircraft																
Estimate distance to flying aircraft																
Lay wire along final protective fire line																
Determine if rivers and streams are fordable																
Identify hand and arm signals with night vision devices																
Secure boat																
Burn garbage and waste																
Calculate distance moved (pacing and offsets)																
Conduct NBC surveys																
Identify a stroke (paddling rate)																
Use NBC equipment to conduct surveys																
Feel tug on tug line																
Identify a sleeping soldier																
Identify trash on the ground																

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem/Bio Decontamination	33 7-3/4-1065 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1027 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Mark mine	2	2										
Move bent over (when approaching helicopters)	2	2										
Place filters on flashlight	2	2			1							
Write report on supply status	2	2										
Check proper wearing of protective suit	1	1										
Employ probes (for mines)	1	1										
Identify jet aircraft	1	1				1						
Inspect boats	1	1						1				
Position antitank mines	1	1										
Draw charts and diagrams	1	1										
Draw range card	1	1										
Enter bunker through rear entrance	1	1										
Guide squad and squad members	1	1										
Hang camouflage net	1	1										
Identify boat obstacles or hazards	1	1										
Identify shadows	1	1										
Move during limited visibility	1	1										
Use tug line	1	1										
Assemble crossing equipmt. (ropes & ponchos)	1	1										
Discern own rate of movement	1	1										
Draw control features on map	1	1										
Identify overhanging branches	1	1										
Identify puddles	1	1										
Mark taut trip wire	1	1										
Mark weapon position	1	1										
Move by high crawl	1	1										
Sit in vehicle	1	1										
Inspect condition of feet	1	1										
Determine location of flying aircraft												
Estimate distance to flying aircraft												
Lay wire along final protective fire line												
Determine if rivers and streams are fordable												
Identify hand and arm signals with night vision devices												
Secure boat												
Burn garbage and waste												
Calculate distance moved (pacing and offsets)												
Conduct NBC surveys												
Identify a stroke (paddling rate)												
Use NBC equipment to conduct surveys												
Feel tug on tug line												
Identify a sleeping soldier												
Identify trash on the ground												

Activity	Total Occurrences of Activity	# Tasks with this Activity	39 7-3/4-1048 Aerial Resupply	40 31-5-0073 Operate in NBC Environ.	41 7-3/4-1052 Cross Chem. Cont. Area	42 31-5-0070 Prepare for NBC Operations	43 7-3/4-1034 Cross Water Obstacle	44 31-5-0103 Infiltrate Area by Land	45 7-3/4-1030 Clear Wood Line	46 7-3/4-1058 Sustain	47 31-5-0108 Estab. Mission Support Site	48 7-3/4-9013 React to Contact
Mark mine	2	2										
Move bent over (when approaching helicopters)	2	2										
Place filters on flashlight	2	2										
Write report on supply status	2	2										
Check proper wearing of protective suit	1	1			1							
Employ probes (for mines)	1	1										
Identify jet aircraft	1	1										
Inspect boats	1	1										
Position antitank mines	1	1										
Draw charts and diagrams	1	1										
Draw range card	1	1										
Enter bunker through rear entrance	1	1										
Guide squad and squad members	1	1										
Hang camouflage net	1	1										
Identify boat obstacles or hazards	1	1										
Identify shadows	1	1										
Move during limited visibility	1	1										
Use tug line	1	1										
Assemble crossing equipmt. (ropes & ponchos)	1	1								1		
Discern own rate of movement	1	1										
Draw control features on map	1	1										
Identify overhanging branches	1	1			1							
Identity puddles	1	1			1							
Mark taut trip wire	1	1										
Mark weapon position	1	1										
Move by high crawl	1	1										
Sit in vehicle	1	1										
Inspect condition of feet	1	1										
Determine location of flying aircraft												
Estimate distance to flying aircraft												
Lay wire along final protective fire line												
Determine if rivers and streams are fordable												
Identify hand and arm signals with night vision devices												
Secure boat												
Burn garbage and waste												
Calculate distance moved (pacing and offsets)												
Conduct NBC surveys												
Identify a stroke (paddling rate)												
Use NBC equipment to conduct surveys												
Feel tug on tug line												
Identify a sleeping soldier												
Identify trash on the ground												

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 31-5-0047 Employ Countermeasures	50 7-3/4-1057 Prepare for Combat	51 7-3/4-1077 Cross Nucl. Cont. Area	52 31-5-0123 Exfiltrate by Air	53 31-5-02020 Confirm Operation Plan	54 7-3/4-1050 Prepare for Chem Attack	55 31-5-0075 Radiological Decontamination	56 31-5-0072 React to Nuclear Strike	57 7-3-1042 Reconnoiter Area	58 7-3/4-1033 Boat Movement
Mark mine	2	2										
Move bent over (when approaching helicopters)	2	2				1						
Place filters on flashlight	2	2										
Write report on supply status	2	2		1					1			
Check proper wearing of protective suit	1	1										
Employ probes (for mines)	1	1										
Identify jet aircraft	1	1										
Inspect boats	1	1										
Position antitank mines	1	1										
Draw charts and diagrams	1	1										
Draw range card	1	1										
Enter bunker through rear entrance	1	1										
Guide squad and squad members	1	1										
Hang camouflage net	1	1										
Identify boat obstacles or hazards	1	1										1
Identify shadows	1	1										
Move during limited visibility	1	1										
Use tug line	1	1										
Assemble crossing equipmt. (ropes & ponchos)	[illegible]	1										
Discern own rate of movement	[illegible]	1										
Draw control features on map	1	1										
Identify overhanging branches	1	1										
Identify puddles	[illegible]	1										
Mark taut trip wire	1	1										
Mark weapon position	1	1										
Move by high crawl	1	1										
Sit in vehicle	1	1										
Inspect condition of feet	1	1										
Determine location of flying aircraft												
Estimate distance to flying aircraft												
Lay wire along final protective fire line												
Determine if rivers and streams are fordable												
Identify hand and arm signals with night vision devices												
Secure boat												
Burn garbage and waste												
Calculate distance moved (pacing and offsets)												
Conduct NBC surveys												
Identify a stroke (paddling rate)												
Use NBC equipment to conduct surveys												
Feel tug on tug line												
Identify a sleeping soldier												
Identify trash on the ground												

Activity	Total Occurrences of Activity	# Tasks with this Activity	React to Nuclear Attack (57, 7-3/4-7012)	Prepare for Nuc. Attack (60, 7-3/4-1051)	Infiltrate by Air (61, 31-5-0023)	React to Chemical Attack (62, 7-3/4-9011)	React to Chem or Bio Attack (63, 31-5-0071)	Prepare for Exfiltration (64, 31-5-0113)	Conduct Assembly (65, 31-5-0019)	Control Info Dissemination (66, 31-5-0044)	React to Indirect Fire (67, 7-3/4-9003)
Mark mine	2	2									
Move bent over (when approaching helicopters)	2	2									
Place filters on flashlight	2	2									
Write report on supply status	2	2									
Check proper wearing of protective suit	1	1									
Employ probes (for mines)	1	1									
Identify jet aircraft	1	1									
Inspect boats	1	1									
Position antitank mines	1	1									
Draw charts and diagrams	1	1									
Draw range card	1	1									
Enter bunker through rear entrance	1	1									
Guide squad and squad members	1	1									
Hang camouflage net	1	1									
Identify boat obstacles or hazards	1	1									
Identify shadows	1	1									
Move during limited visibility	1	1									
Use tug line	1	1									
Assemble crossing equipmt. (ropes & punchus)	1	1									
Discern own rate of movement	1	1									
Draw control features on map	1	1									
Identify overhanging branches	1	1									
Identify puddles	1	1									
Mark taut trip wire	1	1									
Mark weapon position	1	1									
Move by high crawl	1	1									
Sit in vehicle	1	1									
Inspect condition of feet	1	1									
Determine location of flying aircraft											
Estimate distance to flying aircraft											
Lay wire along final protective fire line											
Determine if rivers and streams are fordable											
Identify hand and arm signals with night vision devices											
Secure boat											
Burn garbage and waste											
Calculate distance moved (pacing and offsets)											
Conduct NBC surveys											
Identify a stroke (paddling rate)											
Use NBC equipment to conduct surveys											
Feel tug on tug line											
Identify a sleeping soldier											
Identify track on the ground											

Activity	Total Occurrences of Activity	# Tasks with this Activity	1 7-3/4-1021 Defend	2 7-3/4-1018 Antiarmor Ambush	3 7-3/4-1007 Overwatch	4 7-3/4-1011 Assault	5 7-3/4-1020 Point Ambush	6 7-3/4-1019 Hasty Ambush	7 7-3/4-1025 Move Tactically	8 7-3/4-1012 Knock Out Bunker	9 7-3/4-1054 Clear Building	10 7-3/4-1034 Occupy Patrol Base	11 7-3/4-1015 Clear Trench Line	12 7-3/4-1008 Disengage	13 7-3/4-1028 Cross Danger Area	14 7-3/4-1014 Breach Obstacle
Read a map	52	24	6			1		1	2			3				
Perform chemical decontamination	21	6														
Identify camouflaged individual	17	11	1		3	3	2					1			1	
Remove signs of presence	16	11	1									1				
Move to a location on a map	12	8					1					1		1		
Construct fighting position with overhead cover	11	6	4									1				
Activate demolitions	10	7	2				1									2
Establish cache	10	8														
Camouflage fighting position	9	8	1									1				
Waterproof water-sensitive items	9	8														
Dig hasty fighting position	8	6	3	1												
Camouflage trail after passing	7	7										1				
Remove debris from LZ	7	6														
Perform radiological decontamination	6	2														
Clear an objective	6	4	2			2										1
Remove or tape items which may reflect light	6	3														
Hear covered and concealed firing positions	5	5			1					1						
Lay commo wire	5	4	2													
Cover all reflective surfaces	4	2														
Employ smoke pots	2	2				1										1
Construct obstacle	2	2		1												
Hear relative position of noise	2	2														
Identify good water crossing site	2	1														
Lay wire	2	2														
Camouflage boat	2	2														
Inject Atropine	1	2														
Clear fields of fire	1	1														
Activate a landmine	1	1					1									
Employ demolitions to breach mines	1	1					1									
Feel heat and shock of blast wave	1	1														
Hear location of impact point of indirect fire	1	1	1													
Identify dug in fighting position	1	1			1											
Place wire mesh over windows	1	1														
Blow holes in wall																
Identify extent of injury to soldier																
Identify type of injury to a soldier																
Evacuate casualties	7	5											1			2
Search, gag, and tag POWs	5	4					1	1								
Navigate while afloat	4	3														
Kill a soldier with hands	1	1				1										
Hear ORP locations which are easy to defend																
Construct 1 or 2 rope bridge																

Activity	Total Occurrences of Activity	# Tasks with this Activity	15 7-3/4-1040 Passage of Lines	16 7-3/4-1060 Stay Behind	17 31-5-0110 Establish Surveillance Site	18 31-5-0204 Conduct Recovery Ops.	19 7-3/4-1064 Linkup	20 31-5-0205 Interdict a Target	21 7-3/4-1022 Occupy Assembly Area	22 7-3/4-1047 Consolidate & Reorganize	23 7-3/4-1036 Helicopter Movement	24 7-3/4-1057 Maintain Op. Security	25 31-5-0121 Exfiltrate by Land	26 7-3/4-1055 Defend Built-up Area	27 31-5-0107 Move in Denied Area	28 7-3/4-1043 Occupy Obj Rally PL
Read a map	32	24	2	4	1		7							1	1	
Perform chemical decontamination	21	6														
Identify camouflaged individual	17	11	2				1		1				1			
Remove signs of presence	16	11			2							2		1	1	
Move to a location on a map	12	8	1						1	2						1
Construct fighting position with overhead cover	11	6			2									1		
Activate demolitions	10	7		2				1	1							
Establish cache	10	8		1	1	1		1								
Camouflage fighting position	9	8			2							1				
Waterproof water-sensitive items	9	8														
Dig hasty fighting position	8	6								1				1	1	
Camouflage trail after passing	7	7												1	1	
Remove debris from LZ	7	6			1											
Perform radiological decontamination	6	2														
Clear an objective	6	4														
Remove or tape items which may reflect light	6	3										4				
Hear covered and concealed firing positions	5	5														
Lay commo wire	5	4							1					1		
Cover all reflective surfaces	4	2										3				
Employ smoke pots	2	2														
Construct obstacle	2	2												1		
Hear relative position of noise	2	2														
Identify good water crossing site	2	1														
Lay wire	2	2												1		
Camouflage boat	2	2														
Inject Atropine	1	2														
Clear fields of fire	1	1														
Activate a landmine	1	1														
Employ demolitions to breach mines	1	1														
Feel heat and shock of blast wave	1	1														
Hear location of impact point of indirect fire	1	1														
Identify dug in fighting position	1	1														
Place wire mesh over windows	1	1												1		
Blow holes in wall																
Identify extent of injury to soldier																
Identify type of injury to a soldier																
Evacuate casualties	7	5								2	1					
Search, gag, and tag POWs	5	4				1				2						
Navigate while afloat	4	3														
Kill a soldier with hands	1	1														
Hear ORP locations which are easy to defend																
Construct 1 or 2 rope bridge																

Activity	Total Occurrences of Activity	# Tasks with this Activity	29 7-3/4-9002 Break Contact	30 31-5-0104 Establish Contact w/ Asset	31 31-5-0112 Send Information by Radio	32 31-5-0074 Chem Bio Decontamination	33 7-3/4-1065 Infiltrate/Exfiltrate	34 31-5-0122 Exfiltrate by Water	35 31-5-0009 Infiltrate by Water	36 7-3/4-1069 Occupy OP/Surveil	37 7-3/4-1027 Defend - Air Attack	38 7-3/4-9014 React to Ambush
Read a map	52	24				1	2			3		
Perform chemical decontamination	21	6				5						
Identify camouflaged individual	17	11										
Remove signs of presence	16	11						1				
Move to a location on a map	12	8										
Construct fighting position with overhead cover	11	6										
Activate demolitions	10	7										
Establish cache	10	8						2				
Camouflage fighting position	9	8			1							
Waterproof water-sensitive items	9	6						2	1			
Dig hasty fighting position	8	6										
Camouflage trail after passing	7	7		1								
Remove debris from LZ	7	6						1				
Perform radiological decontamination	6	2										
Clear an objective	6	4										
Remove or tape items which may reflect light	6	3										
Hear covered and concealed firing positions	5	5										1
Lay commo wire	5	4										
Cover all reflective surfaces	4	2										
Employ smoke pots	2	2										
Construct obstacle	2	2										
Hear relative position of noise	2	2										
Identify good water crossing site	2	1										
Lay wire	2	2										
Camouflage boat	2	2										
Inject Atropine	1	2										
Clear fields of fire	1	1										
Activate a landmine	1	1										
Employ demolitions to breach mines	1	1										
Feel heat and shock of blast wave	1	1										
Hear location of impact point of indirect fire	1	1										
Identify dug in fighting position	1	1										
Place wire mesh over windows	1	1										
Blow holes in wall												
Identify extent of injury to soldier												
Identify type of injury to a soldier												
Evacuate casualties	7	5										
Search, gag, and tag POWs	5	4										
Navigate while afloat	4	[illegible]						1	1			
Kill a soldier with hands	1	1										
Hear ORP locations which are easy to defend												
Construct 1 or 2 rope bridge												

Activity	Total Occurrences of Activity	# Tasks with this Activity	39 7-3/4-1048 Aerial Resupply	40 31-5-0073 Operate in NBC Environ.	41 7-3/4-1052 Cross Chem. Cont. Area	42 31-5-0070 Prepare for NBC Operations	43 7-3/4-1034 Cross Water Obstacle	44 31-5-0103 Infiltrate Area by Land	45 7-3/4-1030 Clear Wood Line	46 7-3/4-1058 Sustain	47 31-5-0108 Estab. Mission Support Site	48 7-3/4-9013 React to Contact
Read a map	52	24	1	1	1	1	1				1	
Perform chemical decontamination	21	6		2	2							
Identify camouflaged individual	17	11								1		
Remove signs of presence	16	11	1			1						
Move to a location on a map	12	8										
Construct fighting position with overhead cover	11	6				2					1	
Activate demolitions	10	7									1	
Establish cache	1[illegible]	8								1	1	
Camouflage fighting position	9	8				1						
Waterproof water-sensitive items	9	8		1	1	1	1					
Dig hasty fighting position	8	6	1									
Camouflage trail after passing	7	7				1		1				
Remove debris from LZ	[illegible]	6	1					1				
Perform radiological decontamination	6	2										
Clear an objective	6	4							1			
Remove or tape items which may reflect light	6	3			1							
Hear covered and concealed firing positions	5	5	1				1					
Lay commo wire	5	4									1	
Cover all reflective surfaces	4	2			[illegible]							
Employ smoke pots	2	2										
Construct obstacle	2	2										
Hear relative position of noise	2	2									1	1
Identify good water crossing site	2	1					2					
Lay wire	2	2									1	
Camouflage boat	2	2										
Inject Atropine	1	2			1	1						
Clear fields of fire	1	1									1	
Activate a landmine	1	1										
Employ demolitions to breach mines	1	1										
Feel heat and shock of blast wave	1	1										
Hear location of impact point of indirect fire	1	1										
Identify dug in fighting position	1	1										
Place wire mesh over windows	1	1										
Blow holes in wall												
Identify extent of injury to soldier												
Identify type of injury to a soldier												
Evacuate casualties	7	5			1							
Search, tag, and tag POWs	5	4										
Navigate while afloat	4	3										
Kill a soldier with hands	1	1										
Hear ORP locations which are easy to defend												
Construct 1 or 2 rope bridge												

Activity	Total Occurrences of Activity	# Tasks with this Activity	49 31-5-0047 Employ Countermeasures	50 7-3/4-1057 Prepare for Combat	51 7-3/4-1077 Cross Nucl. Cont. Area	52 31-5-0123 Exfiltrate by Air	53 31-5-02020 Confirm Operation Plan	54 7-3/4-1050 Prepare for Chem. Attack	55 31-5-0075 Radiological Decontamination	56 31-5-0072 React to Nuclear Strike	57 7-3-1042 Reconnoiter Area	58 7-3/4-1033 Boat Movement
Read a map	52	24		2	2		6					1
Perform chemical decontamination	21	6								2		
Identify camouflaged individual	17	11										
Remove signs of presence	16	11										
Move to a location on a map	12	8										
Construct fighting position with overhead cover	11	6										
Activate demolitions	10	7										
Establish cache	10	8										
Camouflage fighting position	9	8					1					
Waterproof water-sensitive items	9	8					1			1		
Dig hasty fighting position	8	6										
Camouflage trail after passing	7	7										
Remove debris from LZ	7	6							1			
Perform radiological decontamination	6	2			1				5			
Clear an objective	6	4										
Remove or tape items which may reflect light	6	3						1				
Hear covered and concealed firing positions	5	5										
Lay commo wire	5	4										
Cover all reflective surfaces	4	2										
Employ smoke pots	2	2										
Construct obstacle	2	2										
Hear relative position of noise	2	2										
Identify good water crossing site	2	1										
Lay wire	2	2										
Camouflage boat	2	2										1
Inject Atropine	1	7										
Clear fields of fire	1	1										
Activate a landmine	1	1										
Employ demolitions to breach mines	1	1										
Feel heat and shock of blast wave	1	1										
Hear location of impact point of indirect fire	1	1										
Identify dug in fighting position	1	1										
Place wire mesh over windows	1	1										
Blow holes in wall												
Identify extent of injury to soldier												
Identify type of injury to a soldier												
Evacuate casualties	7	5										
Search, gag, and tag POWs	5	4										
Navigate while afloat	4	3										2
Kill a soldier with hands	1	1										
Hear ORP locations which are easy to defend												
Construct 1 or 2 rope bridge												

Activity	Total Occurrences of Activity	# Tasks with this Activity	React to Nuclear Attack	Prepare for Nuc. Attack	Infiltrate by Air	React to Chemical Attack	React to Chem or Bio Attack	Prepare for Exfiltration	Conduct Assembly	Control Info Dissemination	React to Indirect Fire
			7-3/4-9012	7-3/4-1051	31-5-0005	7-3/4-9011	31-5-5071	31-5-0113	31-5-0010	31-5-0044	7-3/4-9003
			59	60	61	62	63	64	65	66	67
Read a map	52	24									
Perform chemical decontamination	21	6				2	5				
Identify camouflaged individual	17	11									
Remove signs of presence	16	11						3	2		
Move to a location on a map	12	8			1						
Construct fighting position with overhead cover	11	6									
Activate demolitions	10	7									
Establish cache	10	8						2			
Camouflage fighting position	9	8						1			
Waterproof water-sensitive items	9	8									
Dig hasty fighting position	8	6									
Camouflage trail after passing	7	7						1			
Remove debris from LZ	7	6							2		
Perform radiological decontamination	6	2									
Clear an objective	6	4									
Remove or tape items which may reflect light	6	3									
Hear covered and concealed firing positions	5	5									
Lay commo wire	5	4									
Cover all reflective surfaces	4	2									
Employ smoke pots	2	2									
Construct obstacle	2	2									
Hear relative position of noise	2	2									
Identify good water crossing site	2	1									
Lay wire	2	2									
Camouflage boat	2	2						1			
Inject Atropine	1	2									
Clear fields of fire	1	1									
Activate a landmine	1	1									
Employ demolitions to breach mines	1	1									
Feel heat and shock of blast wave	1	1	1								
Hear location of impact point of indirect fire	1	1									
Identify dug in fighting position	1	1									
Place wire mesh over windows	1	1									
Blow holes in wall											
Identify extent of injury to soldier											
Identify type of injury to a soldier											
Evacuate casualties	7	5									
Search, gag, and tag POWs	5	4									
Navigate while afloat	4	3									
Kill a soldier with hands	1	1									
Hear ORP locations which are easy to defend											
Construct 1 or 2 rope bridge											

			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			7-3/4-1021	7-3/4-1018	7-3/4-1007	7-3/4-1011	7-3/4-1020	7-3/4-1019	7-3/4-1025	7-3/4-1012	7-3/4-1054	7-3/4-1044	7-3/4-1015	7-3/4-1008	7-3/4-1028	7-3/4-1014
			Defend	Antiarmor Ambush	Overwatch	Assault	Point Ambush	Hasty Ambush	Move Tactically	Knock Out Bunker	Clear Building	Occupy Patrol Base	Clear Trench Line	Disengage	Cross Danger Area	Breach Obstacle
Sum of All Activities	3484		260	101	120	99	91	73	118	48	62	85	68	63	48	91
No. of Unique Activities		230	72	48	46	51	50	40	37	33	39	48	36	34	27	39
No. Near-Term Activities		83	35	30	30	28	27	26	21	21	20	19	19	16	16	15
% Near-Term Activities		36%	49%	63%	65%	55%	54%	65%	57%	60%	51%	40%	53%	47%	59%	38%
No. Mid-Term Activities		110	27	16	13	18	17	12	15	13	19	22	16	17	10	20
% Mid-Term Activities		46%	38%	33%	28%	35%	34%	30%	41%	37%	49%	46%	44%	50%	37%	51%
No. Far-Term Activities		37	10	2	3	5	6	2	1	1	0	7	1	1	1	4
% Far-Term Activities		16%	14%	4%	7%	10%	12%	5%	3%	3%	0%	15%	3%	3%	4%	10%

			15	16	17	18	19	20	21	22	23	24	25	26	27	28
			7-3/4-1040	7-3/4-1040	31-5-0110	31-5-0204	7-3/4-1064	31-5-0203	7-3/4-1022	7-3/4-1047	7-3/4-1036	7-3/4-1057	31-5-0121	7-3/4-1055	31-5-0107	7-3/4-1041
			Passage of Lines	Stay Behind	Establish Surveillance Site	Conduct Recovery Ops.	Linkup	Interdict a Target	Occupy Assembly Area	Consolidate & Reorganize	Helicopter Movement	Maintain Op. Security	Exfiltrate by Land	Defend Build-up Area	Move in Denied Area	Occupy Obj. Rally Pt.
Sum of All Activities	3484		89	58	46	71	73	67	60	52	50	45	50	64	35	32
No. of Unique Activities		230	31	30	30	30	23	28	28	25	26	25	18	38	26	20
No. Near-Term Activities		83	15	15	15	13	13	12	12	12	11	11	11	10	10	10
% Near-Term Activities		36%	48%	50%	50%	43%	57%	43%	43%	48%	42%	44%	61%	26%	38%	50%
No. Mid-Term Activities		110	13	12	9	15	8	14	12	9	14	10	6	19	12	9
% Mid-Term Activities		48%	42%	40%	30%	50%	35%	50%	43%	36%	54%	40%	33%	50%	46%	45%
No. Far-Term Activities		37	3	3	6	2	2	2	6	4	1	4	1	9	4	1
% Far-Term Activities		16%	10%	10%	20%	7%	9%	7%	14%	16%	4%	16%	6%	24%	15%	5%

			29	30	31	32	33	34	35	36	37	38
			7-3/4-9002	31-5-0104	31-5-0112	31-5-0074	7-3/4-1065	31-5-0122	31-5-0009	7-3/4-1069	7-3/4-1027	7-3/4-9014
			Break Contact	Establish Contact w/ Asset	Send Information by Radio	Chem/Bio Decontamination	Infiltrate/Exfiltrate	Exfiltrate by Water	Infiltrate by Water	Occupy OP/Surveil	Defend Air Attack	React to Ambush
Sum of All Activities	3484		20	35	15	86	44	44	37	34	30	37
No. of Unique Activities		230	18	18	12	26	18	20	16	15	14	14
No. Near-Term Activities		83	10	10	10	9	9	9	9	9	9	9
% Near-Term Activities		36%	56%	56%	83%	35%	50%	45%	56%	60%	64%	64%
No. Mid-Term Activities		110	8	7	1	15	8	6	5	5	5	4
% Mid-Term Activities		48%	44%	39%	8%	58%	44%	30%	31%	33%	36%	29%
No. Far-Term Activities		37	0	1	1	2	1	5	2	1	0	1
% Far-Term Activities		16%	0%	6%	8%	8%	6%	25%	13%	7%	0%	7%

			39	40	41	42	43	44	45	46	47	48
			7-3/4-1048	31-5-0073	7-3/4-1052	31-5-0070	7-3/4-1034	31-5-0103	7-3/4-1030	7-3/4-1055	31-5-0158	7-3/4-9013
			Aerial Resupply	Operate in NBC Environ.	Cross Chem. Cont. Area	Prepare for NBC Operations	Cross Water Obstacle	Infiltrate Area by Land	Clear Wood Line	Sustain	Estab. Mission Support Site	React to Contact
Sum of All Activities	3484		45	38	43	64	33	36	32	62	35	23
No. of Unique Activities		230	26	24	26	24	21	17	16	18	23	12
No. Near-Term Activities		83	8	8	8	8	8	8	8	7	7	7
% Near-Term Activities		36%	31%	33%	31%	33%	38%	47%	50%	39%	30%	58%
No. Mid-Term Activities		110	13	13	11	9	9	7	7	9	8	4
% Mid-Term Activities		48%	50%	54%	42%	38%	43%	41%	44%	50%	35%	33%
No. Far-Term Activities		37	5	3	7	7	4	2	1	2	8	1
% Far-Term Activities		16%	19%	13%	27%	29%	19%	12%	6%	11%	35%	8%

			49	50	51	52	53	54	55	56	57	58
			31-5-0047	7-3/4-1057	7-3/4-1077	31-5-0123	31-5-02020	7-3/4-1050	31-5-0075	31-5-0072	7-3-1042	7-3/4-1033
			Employ Countermeasures	Prepare for Combat	Cross Nucl. Cont. Area	Exfiltrate by Air	Confirm Operation Plan	Prepare for Chem. Attack	Radiological Decontamination	React to Nuclear Strike	Reconnoiter Area	Boat Movement
Sum of All Activities	3484		21	116	83	20	49	15	44	31	26	24
No. of Unique Activities		233	10	20	19	13	15	9	22	17	13	15
No. Near-Term Activities		83	7	6	6	6	6	6	5	5	5	5
% Near-Term Activities		36%	70%	30%	32%	46%	40%	67%	23%	29%	38%	33%
No. Mid-Term Activities		110	3	13	11	7	6	2	15	10	8	7
% Mid-Term Activities		48%	30%	65%	58%	54%	40%	22%	68%	59%	62%	47%
No. Far-Term Activities		37	0	1	2	0	3	1	2	2	0	3
% Far-Term Activities		16%	0%	5%	11%	0%	20%	11%	9%	12%	0%	20%

			59	60	61	62	63	64	65	66	67
			7-3/4-9012	7-3/4-1051	31-5-0005	7-3/4-9031	31-5-0071	31-5-0113	31-5-0018	31-5-0044	7-3/4-9003
			React to Nuclear Attack	Prepare for Nuc. Attack	Infiltrate by Air	React to Chemical Attack	React to Chem or Bio Attack	Prepare for Exfiltration	Conduct Assembly	Control Info Dissemination	React to Indirect Fire
Sum of All Activities	3484		17	17	38	13	30	15	8	10	10
No. of Unique Activities		230	12	10	13	9	12	10	6	4	6
No. Near-Term Activities		83	5	5	4	4	3	3	3	3	2
% Near-Term Activities		36%	42%	50%	31%	44%	25%	30%	50%	75%	33%
No. Mid-Term Activities		110	6	5	8	4	8	2	1	1	4
% Mid-Term Activities		48%	50%	50%	62%	44%	67%	20%	17%	25%	67%
No. Far-Term Activities		37	1	0	1	1	1	5	2	0	0
% Far-Term Activities		16%	8%	0%	8%	11%	8%	50%	33%	0%	0%

APPENDIX E: HARDWARE AND SOFTWARE REQUIREMENTS FOR THE ICS TESTBED

Table 1 Hardware Possibilities for the O/E Workstation

Hardware Requirement	Initial Operational Capability	Block 1 Upgrades	Block 2 Upgrades
Computer	*SGI Crimson VTX*, *HP* or *Sun* equiv. workstation	No Change	No Change
Printer	Any compatible commercial color laser printer	No Change	No Change
Recording Resources	Data-commercial optical disk Video/Audio - any commercial U-Matic VCR with computer control	No Change	No Change
Imaging Displays	Any compatible commercial high-resolution color monitors	HMD for test subject view.	High resolution HMD for test subject view
Data/Graphic Display	High resolution color monitor provided with workstation	No Change	No Change
3-D Sound System	*Crystal River Labs Convolvotron*, good quality commercial stereo earphones	No Change	No Change
Audio Intercom	Commercial-off-the-shelf	No Change	No Change
Remote Voice Communications	Telephone or intercom depending on proximity	No Change	No Change
6-DOF Controller	*Spaceball™*	No Change	No Change
ASCII Keyboard	Provided with workstation	No Change	No Change
Mouse	Provided with workstation	No Change	No Change

Table 2 Hardware Possibilities for the ICS Authoring Workstation

Hardware Requirement	Initial Operational Capability	Block 1 Upgrades	Block 2 Upgrades
Computer	*SGI Crimson VTX*, *HP* or *Sun* equiv. workstation	No Change	No Change
Printer	Any compatible commercial color laser printer. May be timeshared with O/E workstation.	No Change	No Change
Data/Graphic Display	High resolution color monitor provided with workstation	No Change	No Change
ASCII Keyboard	Provided with workstation	No Change	No Change
Mouse	Provided with workstation	No Change	No Change
Graphics Tablet		No Change	No Change
Scanner	Compatible (RS-422) commercial-off-the-shelf 2D 600 dpi 24 bit color	No Change	*Laser Design Inc. Surveyor™ 3D Digitizer*

Table 3 ICS Authoring Station Software Possibilities

Software Requirement	Initial Operational Capability	Block 1 Upgrade	Block 2 Upgrade
Neutral Database for ICS Simulation development	SIMNET Hunter-Liggett 100 meter database	*Nascent Systems* Corp. Hunter-Liggett 1 meter database	Custom Hunter-Liggett 2.5 cm database
Data Libraries/Data Translation	COTS services - Viewpoint Engineering, COTS libraries - *Viewpoint, Macromedia, NEC*	No Change	No Change
Data Translation	COTS software - Octree and Custom Dev'lp as appropriate	No Change	No Change
Data Creation and Manipulation	COTS software - Software Systems MultiGen, SoftImage, Alias,	No Change	No Change
Data Optimization	Custom dev'lp MODSIM type simulation model architecture to allow models to comm. with each other	No Change	No Change
Data to Objects descriptions via "Forms"	Custom dev'lp of GUI input screens to allow description of Objects, their characteristics, world effects, interactions, etc.	No Change	No Change
Logic Libraries - general purpose simulation models	GFE for some dynamic models COTS s/w - sim. model dev'lp environments CACI MODSIM	No Change	No Change
Logic Translation	Custom dev'lp s/w	No Change	No Change

Table 3 ICS Authoring Station Software Possibilities (cont'd)

Software Requirement	Initial Operational Capability	Block 1 Upgrade	Block 2 Upgrade
Logic Creation and Manipulation	Custom dev'lp s/w	No Change	No Change
Logic Optimization	Custom dev'lp s/w	No Change	No Change
Code Libraries - release and configuration control	COTS options with COTS workstation	No Change	No Change
Code Translation	Custom dev'lp s/w	No Change	No Change
Code Creation and Manipulation - compiler and development environment	COTS with workstation	No Change	No Change
Code Optimization, Integration and Debug	COTS with workstation	No Change	No Change
3D Digitizer Support	None	No Change	*Laser Design Inc. DataSculpt™*
On-Line Help Support	Custom integration Custom and COTS system development	No Change	No Change

Table 4 ICS Cueing Display Hardware

Human Sense Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Vision	Virtual Battlefield Visualization	• Direct-View, Front or Rear Projected[10] • FOV ± 110° Az, +30° to -45° Elev, • Resolution ≤ 4 Arc Minute /Pixel (3300H X 1125V) • 30 Hz Update • Multi-Channel • Full Color	• High Performance HMD • IFOV 60° Each Eye Diagonal Overlapped Binoc. Stereo, • Total FOV 360° Az, 180° Elev • Resolution ≤ 2 Arc Minute / Pixel (1440H X 1080V Each Channel) • 30 Hz Update • 2 Channels • Full Color • *CAE Fiber Optic HMD*	• Very High Performance HMD • IFOV 100° Each Eye Diagonal Overlapped Binoc. Stereo • Total FOV 360° Az, 180° Elev • Resolution ≤ 2 Arc Minute / Pixel (2400H X 1800V Each Channel) • ≤ 30 Hz Update • 2 Channels • Full Color
	Visual Isolation	Experimental Enclosure	HMD	HMD

Table 4 ICS Cueing Display Hardware (cont'd)

Human Sense Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Hearing	Hear intercom and Radio Voices	• Good Quality Wireless Stereo Headset • 20-20,000 Hz Frequency Response • 100 dB Peak, 85 dB Sustained Amplitude	No Change	No Change
	Hear and Localize Battlefield Sounds	• *Crystal River Convolvotron* • Playback Only Sampler • Digital Mixer/Preamp • Audio Amplifiers • Commercial Off-The-Shelf 16 Bit Sound Synthesizer, (e.g. *SimPhonics, Perceptronics*) • Use Headset Referenced Above	• Expanded Sound Storage Capacity	No Change

Table 4 ICS Cueing Display Hardware (cont'd)

Human Sense Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Tactile	Feel Battlefield Surfaces	• Use Instrumented 3D Mockups or Instrumented Real Weapons and Tools	• Model Surfaces and Objects Including Articulated Parts To Use In Virtual Space.	No Change
	Manipulate Objects	• Real Interaction With Articulated Parts of Instrumented Mockups or Weapons/Tools	• Provide Low Resolution (Binary Contact Only) Tactile Display Capable Of Display Of Surface Shape, Location, at	
	Assemble, Carry, and Throw Objects	• Assemble, Carry, and Throw Instrumented Mockups or Weapons/Tools	Feet, Knees, Stomach, Chest, Back, and Buttocks. • Provide Higher Resolution ≥10 tactels/inch with Display of Presence, Temperature, Heat Capacity, Smoothness) at Palm and Fingertips • *CM Research (Thermal Display)* • *Vertex Cyberglove or Teletact Tactile Glove*	

Table 4 ICS Cueing Display Hardware (cont'd)

Human Sense Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Kinesthesia	Display Impenetrability of Surfaces, and Limits to Motion Display Hardness/Resilience of Surfaces Display Resistance Forces	• No Simulation Generated Kinesthetic Cues. All Cues From Natural Results of Use of Props.	• Limited Exoskeleton Providing Approximate Limits to Motion and Reaction Forces To Truck and Extremities Representation Of Limits To Motion(±.5 in), Surface Hardness (Binary -Smooth vs. Rough) and Resistance Forces (± 20% of actual). • *Sarcos Inc. Custom Development*	No Change
Somethesia	Feel Accelerations and Orientation	Not Displayed	Not Displayed	Not Displayed
Olfaction	Smell Environmental Chemicals	Not Displayed	Not Displayed	Not Displayed
Gustatory	Taste Environmental Chemicals	Not Displayed	Not Displayed	Not Displayed

Table 5 ICS Response Transducer Hardware

Human Response Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Sound	Detect Speech	• Commercial Microphone, • 20-5000 Hz Frequency Response • 20 dB Response Sensitivity @ 2000Hz, 90 dB Capability Without Saturation Req'd	No Change	No Change
	Detect Signal Whistle Sound	Detect Expulsion Of Air In Prop Whistle	Detect Expulsion Of Air At Test Subject's Mouth	Detect Expulsion Of Air At Test Subject's Mouth
Movement	Detect Head Orientation and Location	*6 DOF Polhemus FasTrak Magnetic Sensor* Oriented To Neutral Line Of Sight	No Change	No Change
	Detect Body Orientation and Location	Body Suit Measuring Location and Articulation of Trunk, Legs, and Arms. Can Use Multiple, FasTrak	Integral Sensors In Exoskeleton	No Change
	Detect Articulation, Orientation, and Location of Hands, Fingers	*Vertex Technologies CyberGloves*		
	Transduce Manual Control	Commercial 2-Axis Controller	Not Required	Not Required
	Position and Orientation Of Weapons and Tools	*6 DOF Polhemus FasTrak* Sensors Embedded In Props	Not Required, Calculated On Basis Of Virtual Models	Not Required, Calculated On Basis Of Virtual Models
	Operation of Controls on Weapons and Tools	Instrumentation On Props	Virtual Controls On Weapon and Tool Models	No Change

Table 5 ICS Response Transducer Hardware (cont'd)

Human Response Modality	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Force	Detect Force Exerted By Legs, Arms, Body Hands, and Fingers	Integral Sensors In Props	Integral Sensors In Exoskeleton	No Change

Table 6 ICS Computational and Image Generator Hardware

Computer Resource	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
CPU	• Provides Computation Capability As Required By Software. • Support Real-Time Operation • Support Multi-Tasking Operation • Probably Multi-Processor • Performance: TBD MIPS	TBD The requirements may be satisfied with *SGI ONYX,/2 RE2, Harris Nighthawk,* or equivalent.	TBD • Added Database Density, Minimizing Transport Delay (HMD, Exoskeleton) Requires Greater CPU Speed	TBD • Very High Database Density Requires Still Greater CPU Speed
I/O	• Sufficient To Provide Real-Time Access To Interoperating Equipment: TBD • High Speed Interface To Dedicated Graphics Hardware • High Capacity Data Flow Among Distributed Processes/ Processors • Medium Speed Interface To ICS Displays and Transducers • Low Speed Interface to Sound System	TBD • I/O Speed Must Minimize Transport Delay For Head and Body Orientation Sensing • *VL-bus 66MHz Gateway 2000 P.C.*	TBD • Additional High Speed Interfaces Required For HMD and Exoskeleton	TBD
Memory	• Adequate To Maintain Real-Time Simultaneous Execution Of Software Functions	TBD	TBD • High Density Database Requires Increase In Size, Speed	TBD • Higher Density Database Requires Add'nl Increase In Size, Speed

Table 6 ICS Computational and Image Generator Hardware (cont'd)

Computer Resource	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
High Speed Disk Storage	• Sufficient To Store Virtual Battlefield Database and Operating Software • Provide Data At Sufficient Rates To Support Real-Time Operation	TBD	TBD • High Density Database Requires Increase In Size, Speed	TBD • Higher Density Database Requires Add'nl Increase In Size, Speed
Other Peripherals	• Removable Media Mass Storage (Cartridge Tape)	TBD	TBD • Increased removable devices to support the increased size of data files	TBD • Increased removable devices to support the increased size of data files
Commo.	• OSI Network and Communications Support.	TBD	TBD • Increased bandwidth to support increased network traffic	TBD • Increased bandwidth to support increased network traffic

Table 6 ICS Computational and Image Generator Hardware (cont'd)

Computer Resource	Function	IOC Hardware	Block 1 Upgrade	Block 2 Upgrade
Graphics	• Integrated or Stand-Alone Computer Image Generation Compatible With Display Requirements	• Multi-Channel • Total FOV ± 110° Az, +30° to –45° Elev, • Resolution ≤ 4 Arc Minute /Pixel (3300H X 1125V) • 30 Hz Update • Full Color • 5000 Polygons / Channel • Average Polygon Size = 1.82° 2 • Adequate Number Of Moving Models (≤ 80) and Coordinate Sets To Support Interoperating Virtual Platforms And Model Articulation	• IFOV 60° Each Eye Diagonal Overlapped Binoc. Stereo HMD's, • Total FOV 360° Az, 180° Elev • Resolution ≤ 2 Arc Minute / Pixel (1440H X 1080V Each Channel) • 30 Hz Update • 2 Channels • Full Color • 20,000 Polygons / Channel • Average Polygon Size = 0.29° 2 • Increased Number of Moving Models (≥160)	• IFOV 100° Each Eye Diagonal Overlapped Binoc. Stereo HMD's, • Total FOV 360° Az, 180° Elev • Resolution ≤ 2 Arc Minute/ Pixel (2400H X 1800V Each Channel) • ≤ 30 Hz Update • 2 Channels • Full Color • 100-500,000 Polygons/ Channel • Average Polygon Size = 0.10° 2 • Increased Number of Moving Models (≥320)

Table 7 ICS Computational Software

Computer Software Module	Function	IOC Software	Block 1 Upgrade	Block 2 Upgrade
Physical Cueing	Sound synthesis Surface location and feel characteristics Environmental Sound Vibration and Buffet	• Commercial off the shelf software packages are available for the hardware suggested in ICS Cueing Display Hardware Table • Parametrically generated and digitally replayed audio and sub acoustic vibration • 20-20,000 Hz Frequency Response • 100 dB Peak, 85 dB Sustained Amplitude • Read and Interpret CyberGlove	• Increase in quantity of sound files required but no upgrades to the software • Model Surfaces and Objects Including Articulated Parts To Use In Virtual Space.	• Increase in quantity of sound files required but no upgrades to the software
User Interface	User Interface I/O A/D, D/A Conversion Data, Video, Audio Switching Tactile Display Driver Thermal Display Driver	• Commercial off the shelf software packages for Analog to Digital and Digital to Analog conversions • Shared Memory Access	• Digital signal conditioning software	• Not required
Kinesthetic Cueing	Kinesthetic Models Exoskeleton	Kinesthetic cueing models for the weapons and tools if recoil and reaction forces provided under computer control.	• Dynamic models of the human body • Dynamic models of weapons and tools • Operating software for exoskeleton	• No change

Table 7 ICS Computational Software (cont'd)

Computer Software Module	Function	IOC Software	Block 1 Upgrade	Block 2 Upgrade
Battlefield Physics Computations	Local Terrain Characteristics Terrain Dynamics Collision Dynamics Gravity Friction Effects, Fluid Flow, Reflection/Refraction of Light, Platform Dynamics	• Simulation models for vehicles, environment and the individual combatant • Virtual World Physics	• New Models	• New Models
Nav/Comm	Nav Calculations Radio Model RF Propagation Compass	• Communication propagation models • Compass Simulation	• Telephone Network Model	• No change
Weapons Simulations and Effects Computations	Ballistic computations Damage determination Ammunition Inventory Own Weapons Model Threat Weapons Model	• Weapon models of the M-16, LAW, Dragon, M-60, Demolitions, etc.	• Models of Hand Grenades, Early Warning Devices and Detonators, and Claymore Mines	• No change
Visual Environment Generation	Virtual Object Models Terrain Model Image Generation Moving Models Visual Database/Gaming Area Visual Scene Environment Occultation Visual Crew Station Interface Visual Aircraft Systems Interface Visual Display Systems	• 100 Meter Terrain Database • Local Terrain Patch Swapping	• New 1 Meter Terrain Database • Improve Resolution, FOV	• New 2.5 cm Terrain Database • Improve Resolution, FOV

Table 7 ICS Computational Software (cont'd)

Computer Software Module	Function	IOC Software	Block 1 Upgrade	Block 2 Upgrade
Terrain/ Natural Environments Computations and Network Interface	Network Interface Terrain Database Line of Sight Calculations Simulation Executive Status and Control Scenario Control Remote Entity Approximation Performance Monitoring and Measurement Multiple Simulator Environment Interaction Atmosphere Height Above Terrain Occulting Database Management Collision Detection	• System Executive • Simulation Manager • Performance Measure Sampling and Transmission • Database Engine • Environmental Database • 100 M Terrain Database • DIS Cell Interface Unit	• New 1 Meter Terrain Database • Update Performance Measures	• New 2.5 cm Terrain Database • Update Performance Measures